TRAVELLER®

STARSHIP OPERATOR'S MANUAL

SCIENCE FICTION ADVENTURE IN THE FAR FUTURE

TRAVELLER®

STARSHIP OPERATOR'S MANUAL

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FOREWORD

This is a book about starship operations. Starships are part of the central focus of *Traveller*, which is about working together to solve problems and have adventures. The primary intent of this book is to provide context and detail for life aboard a starship, whether to inspire entire campaign plots or simply add detail to slice-of-life scenes. However, there is more to this book than just that.

From its first release in 1977 to the publication of this book, there have been several editions of *Traveller*. Each gives a different spin on how to play games by telling tales of Travellers in space. Doubtless there will be more editions after these words have been committed to ink. While the basics remain the same, such as the use of jump drive to travel faster than light, each edition emphasised different details, leading to confusion, and conflicts when players have attempted to take material from different editions to weave the tale they wish to tell.

This book is meant, in part, to smooth over such conflicts. It takes material from Mongoose's works, my own *Traveller5*, and more, weaving them together into a coherent story extending where possible from real world science, including developments since 1977. For example, while we do not have artificial gravity yet it seems likely, assuming it is possible, that it may extend from quantum gravity manipulation, which implies certain details of how it would work in practice. We know that gravity propagates by waves and that signals propagated by waves can be shaped by beamforming techniques. It is likely these same techniques would be applied to manufactured gravity.

Since the focus of this book is on the narrative and the content is intended to be useful across editions, a minimum of game mechanics are present. Sharp-eyed readers will find a few exceptions but these have been phrased to be adaptable to your edition of choice.

Keep in mind that this is only a story. The Official Traveller Universe is but one story that can be told with the *Traveller* rulesets and even then, the contents of this book are presented from the perspective of certain individuals in the Third Imperium in 1105. If you wish to run a campaign in a different setting, whether a different time or place in the OTU or in some other universe entirely, use as much or as little of this as you want.

Keep travelling,

INTRODUCTION

Congratulations on the acquisition of your ship! This overview introduces you to the common objects and systems found on most starships. While this book cannot cover the specifics of every modification, variation and implementation, it tries to cover items of use to you as you operate your new or used ship.

For technical specifications of your ship, please refer to your maintenance manual. This book focuses on 100-to-200 ton commercial ships. If you need emergency assistance or wish to know about a specific topic, refer to the Table of Contents.

This book has two main sections. First is a description of the major components of starships, system-by-system, starting with the most vital, then notes on less common crew roles and typical concerns when maintaining and building ships. A comparison of three common ships follows – the *Animal*-class safari ship, the *Suleiman*-class scout/courier and the *Empress Marava*-class far trader – as examples of similarities and differences among smaller starships.

This manual covers the operation of starships, extending beyond the core systems of piloting and engineering. Many who serve aboard ships have other no less essential functions, such as brokers to optimise the value of cargo a trading ship delivers, survey specialists to test an unmapped world for colonisation or stewards to attend to the needs of passengers. They should be considered crew just the same as the pilot or engineers. This manual is intended for their perusal as well, to improve understanding of and interactions with crew considered more immediately vital to the ship's operations. Knowing the main systems of a starship can save your life and the lives of your fellow crewmates.

This book covers insight from crews that have served aboard a wide variety of spacecraft. Many of the skills learned from one spacecraft mission apply to others readily enough but some may be more specific; the crew of a passenger liner may know as much about sensor operation as a survey ship's crew knows about entertainment but both are valuable in their own right. This does not extend into the quirks of every individual class, as the number of spacecraft classes – let alone variations – in Charted Space is beyond counting. Compiling a single definitive database of every spacecraft class in operation in the Third Imperium, let alone every class that has ever existed in Charted Space, may be impossible.

LIVING WITH HIGHER TECHNOLOGY

A special note for readers from worlds of TL8 and below, for whom gravitics and fusion power are not staples of daily life: if you have secured a spot on a starship crew, you are going to have to adjust to life on a starship, fast. This book can help you do that.

First off, do not worry about getting accustomed to gravitics, despite how vital a role it will play in your life aboard ship. Artificial gravity is mostly about keeping things the same as you are used to. Making cargo and people float around is easy but not useful for most things you will do. Manoeuvre drives and other external systems are things the ship does, not things you directly experience unless they go very wrong.

The biggest practical change you will meet is that mass is sharply limited but energy is in abundance, relative to what you are used to. This changes the preferred approach to many situations. There will be a higher degree of robotic assistance, among other tools you may not recognise. For example, you might be used to flushing chemical drain cleaner down a clogged pipe. On your world there may be a factory making this chemical but on a ship it would be a non-renewable mass, with no guaranteed way to replace it until the next time the ship restocks at a major port, as minor ports might not carry this resource. Instead, a robot can crawl outside the pipe, image inside it without breaking the pipe, then employ ultrasonics or gravitic tools at the sticking point to peel off the clog.

Avoid committing pranks that will consume mass, either directly or to clean up. Ruining the food supply, especially while not at port, is a classic way to earn the ire of your crewmates. Faking emergency calls or simply annoying well-armed starports or military vessels is a bad idea. Even if your crew strikes you as particularly informal, as is the case for many crews that have room for a low-TL member, it never hurts to act professionally while on the job. This will make your life easier, more comfortable and may save your life from some of the many dangers of space.

Humaniti has travelled the stars for thousands of years and most of it is well-documented. Learn from that and compare new ideas you come up with to what others created before. New circumstances, particularly new technology or discoveries, can invalidate this prior wisdom but rarely entirely. Your world or family might possess some unique insights but, while planning, check guides like this to see if your idea has been attempted previously. If one of your crew members has awed you with impossibly profound wisdom, there is a good chance this is how they learned it. You may as well copy that trick.

A version of this warning applies to those who come from high technology, high population worlds, where supplies of a wide range of goods are available in abundance and on demand. Once a ship leaves port, supplies are limited to what it carries and what it can manufacture until it reaches the next major port: a Class D or E starport might not have food for sale, let alone spare parts. The general advice to carry supplies for four weeks, even if the plan is to head straight from one major port to another, applies to food and personal consumables as well as fuel. Meal planning and other home economics skills can help avoid running out of food mid-jump but there is a limit to how far supplies can be stretched.

Every spacecraft is made to perform a certain range of functions. While some fulfil their intended role better than others, few are complete failures. Practically without exception, additional uses have been found for any class of spacecraft. There are inevitably design quirks that make a ship hard to use for one purpose but perfect for another. A ship designer can only imagine how a ship would be used, where people who have worked, lived on and refitted a ship can point out improvements. More importantly, the lifespan of most ships far exceeds the length of time typically spent developing a new ship class. A ship designer does not always see these quirks manifest before the ship is constructed and tested.

This lack of foresight can be seen in the cramped cargo hold access in the Suleiman deckplan in the Ship Walkthrough chapter, along with the problematic airlock to holding pen route of the Animal class. This book also covers how to modify a ship to fix such issues, or otherwise work around them, to help you become a knowledgeable and confident starship operator regardless of the ship you serve on.

Not all ships have the same mission. Parts of this book speak more to certain ship types more than others. For example, neither the *Suleiman* nor the *Animal* are designed to handle 4A cargo containers but an *Empress Marava* can and often does. Some details of sensors and communicators are there to help deal with the sort of anomalies that a scout such as the *Suleiman* routinely sees, which are less likely to be of use to *Animal* or *Empress Marava* crews. While *Suleimans* and *Empress Maravas* rarely deal with live cargo, this is more of a concern for the *Animal* class.

TERMINOLOGY

When dealing with starships, it is useful to know the specialised terms used in reference to them. This book leans toward common usage by starship crews in the Third Imperium. See for example the note about the definition of ‘radiation’ on page 30.

SPACECRAFT: A vehicle capable of travelling through space.
STARSHIP: A spacecraft with a jump drive. Also referred to as ‘ship’.
BOAT: A spacecraft that is not a starship.
DISPLACEMENT TON: A measurement of volume equal to one metric ton of liquid hydrogen, roughly 13.5 cubic metres. When discussing spacecraft, ‘ton’ – if not specified or otherwise obvious from context – most often refers to a displacement ton.

DIRECTIONS ABOARD SHIP

In most languages, the terms for directions aboard a spacecraft evolved from those in use on pre-spaceflight wet-navy ships. These are not universal. On some ships

the direction of forward motion aligns with the ship's gravity, perhaps making 'fore' and 'dorsal' the same. In some cases there is no distinct 'port' or 'starboard', while others designate 'fore' based on some feature that is along an edge of the ship such as a primary docking bay.

BOW: Nose of the ship. The direction the ship is usually moving in when underway. **FORE** is toward the bow.
STERN: Rear of the ship. The direction the ship is usually moving away from when underway. **AFT** is toward the stern.
DORSAL: Top surface of the ship, relative to ship's gravity.
VENTRAL: Bottom surface of the ship, relative to ship's gravity.
PORT: Left side of the ship, when facing the bow and the dorsal side is above you.
STARBOARD: Right side of the ship, when facing the bow and the dorsal side is above you.

SHIP TYPES

There is a widespread but technically incorrect trend to refer to the *Suleiman* as 'the Type S class', and to the *Animal* as 'the Type K class'. In truth, there is no such thing as 'the' Type S or Type K. A ship's type refers to its primary mission. The Imperial Navy controls the most widely used registry of mission types, such as C for cruisers. Further codes distinguish subtypes, such as CL or CA. The registry of mission types changes from time-to-time, so outside the core mission type codes, a ship that had one type code some time ago might have a different one now.

It has become common to assign mission type codes to civilian ships to achieve universal coverage. A *Suleiman* is a scout, therefore its mission code is S, so it is a Type S. The *Serpent* class is a scout, therefore it is a Type S as well. However, the *Suleiman* class is much more widely known, so mostly when people hear 'Type S' they think of a *Suleiman*.

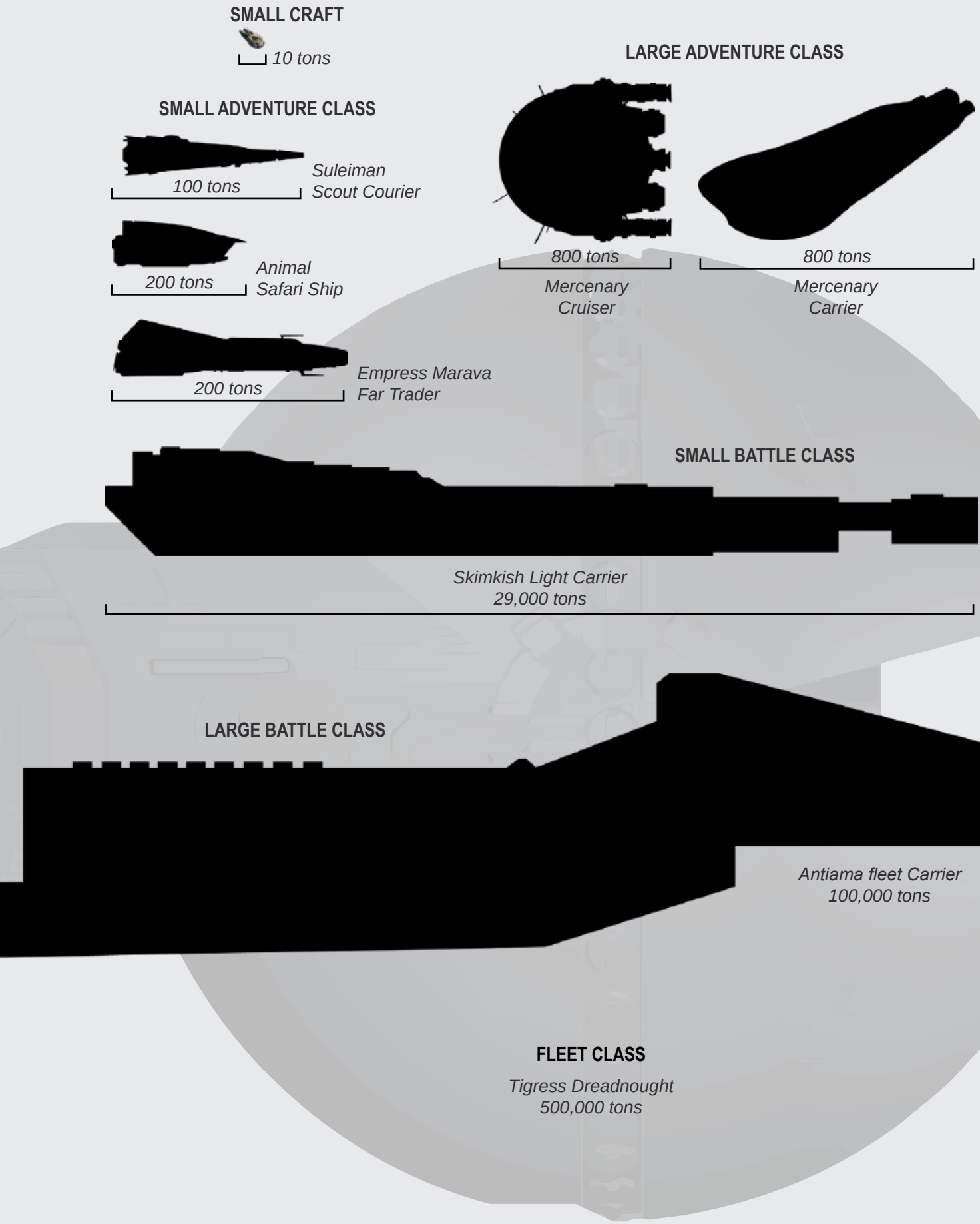
This is particularly relevant to the *Empress Marava* class. Trader ships are Type A. Jump-2 capable trader ships are Type A2. The *Empress Marava* is a well-known Type A2 but so is the *Hero*, a jump-2 version of the *Beowulf*. Since 'the Type A2 class' could refer to either the *Hero* or the *Empress Marava*, not to mention other jump-2 capable trader ship classes of similar specification, 'the Type A2 class' is ambiguous on top of being incorrect.

SIZE CLASSES

Starships are traditionally referred to as being in the adventure, battle, fleet or world classes. Their definitions have varied but are as follows in the modern Third Imperium:

- Spacefaring vessels less than 100 displacement tons are small craft. Being too small to have functioning jump drives, they cannot be starships.
- Any spacecraft at least 100 displacement tons without a jump drive is a big craft, if there is a need to distinguish it from small craft, but is often just called a boat. Patrol boats and system defence boats, most often run by local law enforcement and military respectively, tend to be those of most concern to Travellers. Others are more often concerned with transport boats, asteroid mining boats and other such components of a high technology system's economy.
- Any ship of less than 2,500 displacement tons is sometimes referred to as adventure class. This is by far the majority of all ships in Charted Space and scouts, traders, personal ships and others go in this category. Most used starship sellers deal exclusively in this size.
- Larger than the adventure class but smaller than 250,000 tons is the battle class. Here lie battleships, cruisers, most large transports and freighters, jump tenders and other ships that operate within established interstellar infrastructure. In many cases, the complete list of systems they will ever visit is known before construction begins. Most medium and high population worlds with much interstellar trade see routine visits by ships this large.
- Beyond that but smaller than 1,000,000 displacement tons is the fleet class. Only large polities such as the Third Imperium build ships of this size for military use. More common are the largest of freighters and transports built by megacorporations, plying the wealthiest trade routes where efficiencies of scale can be fully exploited. Most large colony ships fall in this class.
- All larger ships make up the world class. These are rare titanic things of legend, be they superweapons or carriers of entire populations. Even among those who travel the stars for a living, most never encounter one outside of fictional or historical depictions.

As with ship type codes, these terms were originally military, but usage spread over time. They remain in use even if a 500,000 ton colony ship might not lead a fleet and a 200,000 ton freighter will seek to avoid battle.


SMALL CRAFT
10 tons
SMALL ADVENTURE CLASS
100 tons
Suleiman
Scout Courier
200 tons
Animal
Safari Ship
200 tons
Empress Marava
Far Trader
LARGE ADVENTURE CLASS
800 tons
Mercenary
Cruiser
800 tons
Mercenary
Carrier
SMALL BATTLE CLASS
Skimkish Light Carrier
29,000 tons
LARGE BATTLE CLASS
Antiama fleet Carrier
100,000 tons
FLEET CLASS
Tigress Dreadnought
500,000 tons

Hull

A ship's hull is its most important component. If there is only a hull, there is at least a hulk that, in most systems, one can apply for salvage rights to. Without a hull, there is at most a collection of parts and debris. Destruction of a ship's hull is generally recognised as destruction of the ship.

Starship hulls are not a simple mass of inert metal. Jump drive emitters, sensor nodes, lifters along the bottom of the ship and other such systems are woven through material thick enough to hold an atmosphere against both the vacuum of space and enemy action. Some starship technicians consider the hull to be alive, with coolant runs and structural ribs in place of blood and bones.

FEATURES

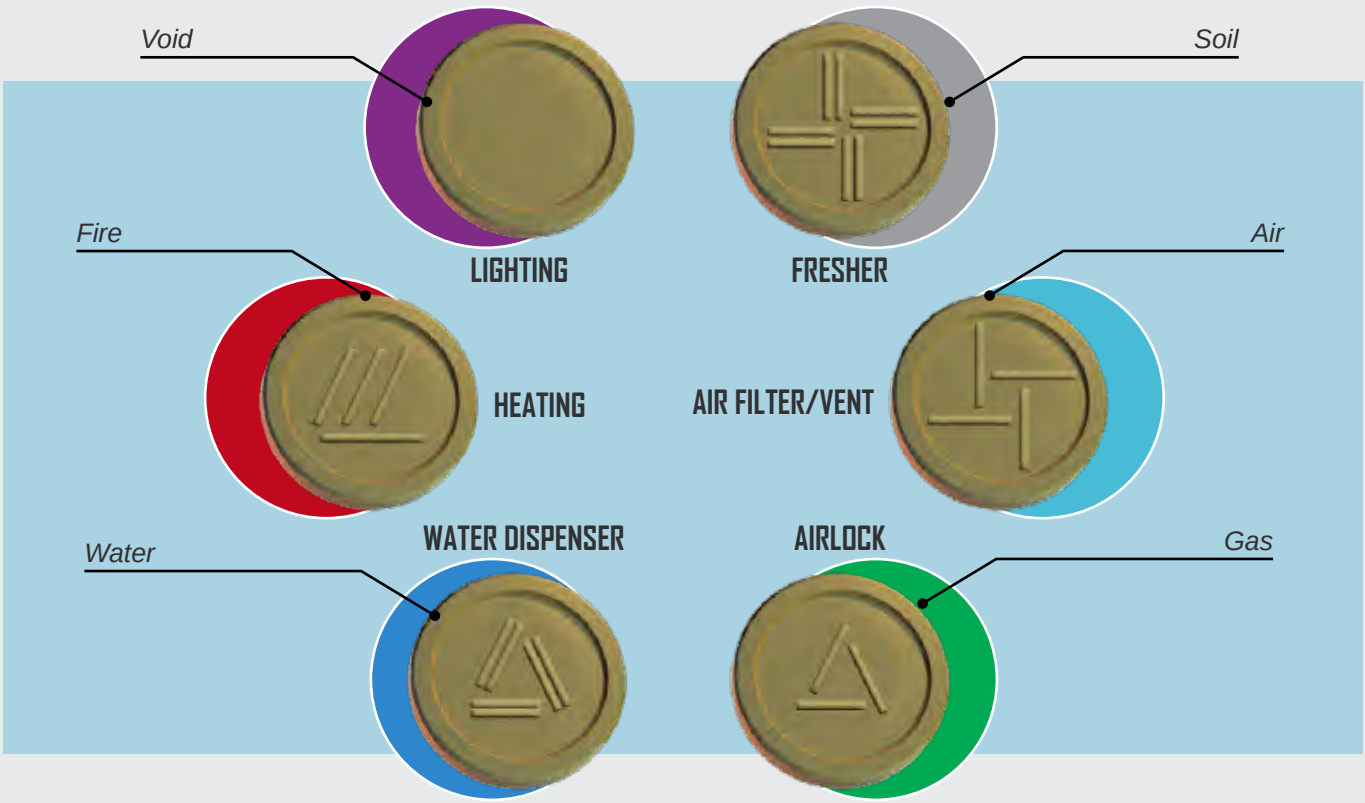
Most spacecraft and space station hulls share the same features, available from TL9 if not earlier. These have been refined over thousands of years and are considered essential to any vehicle worth the title of 'spacecraft'. Notably, most grav vehicles which can reach space lack some of these features; partly the reason why they are not referred to as spacecraft.

ARTIFICIAL GRAVITY AND INTEGRATED LIFTERS

While going without artificial gravity is technically an option, it is so common that most people treat it as a standard feature of all spacecraft. Lifters are marginally rarer but are essential on any spacecraft intended to land. Both systems rely on gravitic technology to function – see the Gravitics chapter on page 74 for more detail. 'Artificial gravity' in common parlance refers specifically to grav plates, as other methods such as spin or thrust gravity can only mimic gravitational acceleration.

ELEMENTS OF LIFE SUPPORT

As discussed more in Life Support, starting on page 25, space is an extremely hostile environment. Thus, most hulls supply the environmental conditions necessary to keep occupants alive. These systems are among the most reliable on a ship and consume negligible power.



SENSOR NODES

As noted in Sensors and Communications, starting on page 66, many ships use their entire length as one large synthetic aperture array. This means distributing cameras, antennas, and other sensor hardware over the hull. Typically, these are in small nodes mounted beneath external armoured ports which are translucent to the signals the sensors are intended to detect.

JUMP DRIVE EMITTERS

Any spacecraft with a jump drive needs a way to enter jumpspace. This takes the form of thousands or millions of emitters built into the hull, with a density comparable to pores on skin. Each emitter must activate in a precise sequence at a rapid pace to make a successful jump entry. Although this is notoriously complex, such that only computer control can perform the task, there is no known alternative. Using a smaller number of emitters or taking several milliseconds between activations results in only part of the hull being covered by the jump bubble before it collapses, resulting in a misjump. The presence of jump drive emitters in every square metre – with the attendant feeds for power, data and jump fuel – is often the easiest way to distinguish hull material intended for starships from that planned for other spacecraft. For more detail on how jump drives work, see page 82.

BASIC RADIATION PROTECTION

Most spacecraft and space station hulls can indefinitely protect their inhabitants from ordinary background radiation and, if a major solar flare threatens, either manoeuvre to place themselves in a shielded location or rotate to place most of their hull between the flare and the crew. On low TL spacecraft this protection comes from mass. Once the technology is available, magnetic fields (tiny, low-powered magnetospheres) are a more practical solution. Nuclear damper technology partially stems from work on these radiation protection systems. For more detail, see Radiation Protection starting on page 30.

HARDPOINTS AND FIRMPOINTS

On modern spacecraft, structural reinforcement as well as power and surface area limitations mean the accepted limit is one ‘hardpoint’ per 100 displacement tons, while small craft have a number of ‘firmpoints’. Most ship-scale weapons take up one of these points, with downrated versions mounted on firmpoints. These points are notional until the hardware and fire control systems are installed. While the cost of this is often negligible next to the cost of the weapon, installing a new weapon system to use a spare hardpoint often requires minor redesign of a ship. Sophonts have been trying to put more weapons on spacecraft for over ten thousand years. Using more weapons on a ship results in structural damage to the ship, the weapons tearing free and/or having insufficient power.

For example, a 200 ton *Animal* could host two weapons but only comes with one double turret. Upgrading the double turret to a triple turret is easier than adding a second turret, thanks to standardised fittings and the complications of hull modification. An informal survey suggests it is more common for those that have two weapons to use their second hardpoint to host a fixed mount weapon than add a second turret or barbette.

More details are in Weapons and Defences, starting on page 99.

SELF-SEALING

Several methods have been developed for hulls to automatically seal small ruptures, such as from micrometeoroids or light weapons fire. Some weave capillaries throughout the hull that extrude sealant when breached, while others have small robots either constantly patrolling or dispatched when a breach is detected. Some employ double hulls – essentially crawlspaces – that contain small breaches to the outer layer, whereas others seal off the affected area internally.

LANDING GEAR

Any ship intended for orbital interface and landing, such as traders intending to use downports, scout ships surveying alien worlds or any sort of transport shuttle, must mount landing gear. Ships planning to solely utilise orbital installations need not bother.

Most ships use pads or skids that extend and retract for landing. Having a pair of skids is simpler than maintaining individual pads and legs on each corner of a ship but is less effective for wilderness landings. Ships with skids are meant to only ever land at starports. Some pads, particularly at higher Tech Levels, can unfold or extend to present more area and thus reduce ground pressure. There are tales of Travellers who landed in the wilderness without a problem, got out of their ship and began sinking into soft ground because the ground pressure of their boots was much greater than the ground pressure of their ship’s landing gear.

To move short distances over the ground, the ship engages lifters to take off, hovering less than a metre if the local terrain is flat, then flies where it needs to go and lands again. Some ships use wheels but these are rare. The most common wheel configuration is three sets, either one under the forward centre and each rear corner

or one under the rear centre and each front corner. They are only useful on streamlined ships without lifters, which rely on traditional aerodynamic lift to leave the ground and can only land at downports with long runways. Even in these cases, it is often simpler to design the ship to land on its manoeuvre or reaction drive, an arrangement called a 'tailsitter', as the engine is at the bottom of the ship rather than the rear.

Points of contact with the ground are often the most reinforced on a ship. In terms of protection from small arms they are equal to bulkheads, although using them for cover in a firefight is not recommended as they often have gaps that bullets can pass through, as well as risking damage to the less-reinforced inner parts of the landing gear. Stability and ground clearance are typical design concerns; well-designed, well-maintained landing gear will insulate the ship from minor ground tremors and allow sophonts to walk under the ship.

CONTROL CENTRE

This refers to any system by which the ship may be controlled. The most common form, a 'bridge', takes the form of a room fulfilling this function through one or more control stations. Alternative forms may be a cockpit on a small craft or a robotic ship's central computer. Whatever form it takes, it is the ship's nerve centre. Many designs make it the most defensible part of the ship. On smaller ships, it is the default location that crew gather during missions for constant updates, as most ship actions can be performed there. This focus of staying on the bridge leads directly to its frequent use as an informal commons, especially on ships without extensive facilities, such as the *Suleiman* class.

In certain military designs, the bridge is at the ship's centre for protection. This would be of little help in any serious combat for most small ships, particularly any with only one or two decks, which lack enough volume to have a large protected core. Otherwise, it is useful to place this area near the bow to give direct lines of sight to nearby close hazards and aid with docking, landing or manoeuvring. Comfort and security can argue for placing the bridge in the bow of non-combat ships. In one case, a trader's competitor gained access to their virtual cockpit and booted up a flight simulator. The trader's crew thought they took off and did a perfect jump entry, only to be awoken 12 hours after their supposed departure by starport security banging on their airlock wanting to know why they were still on the pad and not answering hails. The competitor beat them to the next system, winning a significant contract.

On all but the most relaxed-security ships, access to the bridge is limited to one or a few entrances, with iris valves to maintain pressure if there is a hull breach elsewhere. These will usually be set to open for crew only; non-crew are only permitted as accompanied guests and must leave before the last crew leaves the bridge, in the rare situations where the bridge is unoccupied for any length of time. This protects not just the crew stations but also the vehicle emergency kit described under Emergency Rescue Equipment

on page 33. Some of the bag's contents, in particular the disassembled survival rifle, would be useful to a hijacker if left unsecured.

OPTIONS

Not all hulls are identical. A living ship designed only to hold one standard atmosphere and a dead metal pressure vessel able to handle 100-atmosphere pressures are hard to confuse for one another.

SELF-HEALING ORGANIC AND POLYMER HULLS

Biotech hulls have some ability to regenerate themselves, going well beyond the self-sealing capabilities of most hulls. Engineered from artificial biomass, these hulls contain organic proteins that bond together like a body repairing from a cut or scratch. While this process takes time, it is a marvel to watch as the hull sutures itself back together.

TL10 polymer hulls heal themselves slower than TL12 organic hulls. However, it is much easier to mix more polymer from their base components and repair on the go than for a standard metal hull. New polymer is spread or laid over the hull breach and heated to bond with the old polymer, creating an airtight seal.

NON-GRAVITY HULLS

Not all spacecraft have artificial gravity. Some utilise spin or thrust gravity, while others work with none at all.

With spin gravity, a structure – typically a cylinder or wheel – rotates such that the centrifugal force on someone standing inside it imitates gravity, in a sort of inverse of how orbiting a planet works. This simulated 'gravity' tapers off linearly as one progresses toward the centre: if there is 1G at the outer rim, there is 0.5G halfway to the centre and 0G when at the axis of rotation. This gradient is more intense on smaller ships so it is rarely used, although there are exceptions such as laboratory ships that sometimes run experiments where this is useful. It is more common on cylindrical space stations of a minimum of half a kilometre in diameter, where a non-rotating central axis facilitates docking, with curved elevator tracks accelerating and decelerating passenger transit to and from the rotating outer section. Long-term residents of such stations acclimatise to the subtle differences, such as a Coriolis effect that creates a pull to the right or left when moving with or against the direction of rotation. Manoeuvring is more difficult when employing spin gravity but any modern flight control software is more than up to the task.

Ships meant for long-term habitation without any form of gravity are rare, as almost all sophonts are optimised for existence in a gravity field. The deleterious effects of living in different gravities are well-documented and typically less than those of living in no gravity. While there are treatments and adaptations available, the general medical consensus is that most sophonts should spend a few hours of each day, preferably the majority, in some sort of significant gravity. For humans and others who trace their genetic origins to Terra, the recommended minimum is 0.05G. This is why worlds with less than 0.05G are either not colonised or have artificial gravity plates installed. However, exposure to microgravity is not immediately fatal to most sophonts, so ships without gravity are sometimes constructed, especially by worlds unable to build or buy grav plates, mainly TL7–8 worlds newly establishing or reestablishing spaceflight.

Some non-gravity boats are constructed under the assumption that they will usually be under acceleration provided by reaction drives, thus providing thrust gravity. This assumption is true if there is infrastructure, such as for passenger shuttles, to transfer to at either end of the journey or if the boat is constructed for a single one-way journey, such as cargo or colonist transfer within a system. This is an expensive proposition, so such ships are constructed as cheaply as possible, giving a reputation for unreliability. Without this infrastructure, the vessel winds up spending significant time in orbit or microgravity.

AQUATIC OPTIONS

Most ships can float but many mistake a ship's space worthiness for an ability to go underwater. While going underwater requires the ship to be airtight – which spacecraft are – a much stronger hull is needed to withstand the pressure of ocean water. Most starships are built to withstand pressure differentials of up to one atmosphere. Diving about 10 metres into a typical ocean is equivalent to one atmosphere; the pressure increases the further down a ship goes and, unlike in space, pushes inward rather than out. Gas giants feature high pressure deep in their atmospheres and this is why diving a typical starship deep into an ocean or gas giant is not recommended. A few starships can handle higher pressures thanks to structural reinforcement and good external hatch design, typically research vessels or system defence boats intended for ambushes.

Some aquatic sophonts have found their submersible vehicles work well as the basis for spacecraft designs. Their spacecraft can easily handle the pressure of deep oceans or gas giant atmospheres, making them

popular for those who want to engage in gas giant or underwater mining. Marketing for these ships often compares other ships to tin cans, grapes or other notably non-pressure-resistant objects.

CONFIGURATIONS

The shape of a hull has a significant impact on the craft's flight characteristics when passing through an atmosphere or hydrosphere. While most spacecraft spend the vast majority of their time in space, the tiny minority of time not in a vacuum is vital. Most exceptions travel only from highport to highport, relying on small craft when they need to interact with a world beneath an atmosphere. A hull streamlined for atmosphere manoeuvres well in hydrospheres as well, although optimal liquid-surface performance requires different configurations and diving any significant depth necessitates a pressure-resistant hull. Hull shapes can be broken into four categories.

STREAMLINED, AIRFRAME AND LIFTING BODY

Most small craft and small ships are designed to operate within an atmosphere, in order to access starports on the ground. Many larger ships also make such trips, whether from a need to directly transit atmospheres or just out of tradition from the local shipyards' early days of spaceflight. There is some debate about the maximum theoretical size of ship that could fly in an atmosphere, especially since virtually all ships have manoeuvre drives that would let them 'fly' without streamlining.

Standards bodies do not universally agree about the proper degree of distinction within this category. Some denote all streamlined ships the same, while others distinguish generically streamlined hulls such as bullet and clamshell shapes from those with wings or that are otherwise specifically airframes, as well as from those that go even further and shape the entire hull as one giant lifting body.

Cones, cylinders, disks, domes, needles, rings, saucers, spheres and wedges are common shapes when wings are not used.

STANDARD UNSTREAMLINED

This typical, default shape is optimised for efficient operation in space rather than atmosphere and is thus not streamlined. Some call this 'partially streamlined' to distinguish from hull shapes that are even less capable in the air. Most shapes in this category come in streamlined versions, such as a cylindrical unstreamlined hull that can be given rounded edges and otherwise reshaped into a streamlined cylindrical hull.

Boxy and slab-like hulls are common, as are unstreamlined versions of non-winged streamlined shapes. Spherical hulls without an emphasis on streamlining can be included in this classification.

CLUSTER STRUCTURE

This category typically has two or more hulls, possibly a main hull and one or more subhulls, bound together with struts. These are favoured when certain systems must be kept apart from primary crew space for health or security reasons. Very rarely could these concerns not be dealt with by a more standard hull, although this solution usually works well when employed. They are used when cost is a concern as creating multiple sections separately is faster, cheaper and easier to repair than fabricating a singular cohesive hull. Some groupings distinguish cluster hulls by how close or dispersed the structure is, others by whether there is significant bracing.

Overall shape tends to be less relevant for cluster hulls. Certain sculptors, who fashion small depictions of starships with no need for functionality, prefer cluster hulls for their freedom of expression.

PLANETOID

This style is the least expensive option for a hull that does not have missions requiring passage through an atmosphere. Giant rocks are present in any colonised system but not just any rock will do. Silicate planetoids are preferred over carbonaceous or metallic ones and the rock should be solid rather than a rubble pile, but finding a suitable one rarely takes much effort. Simply locate one of the right size or cut the right size from a larger rock, then drill into it. Planetoid hulls are shaped like the rocks they came from but when a hull is cut from a larger rock, common construction techniques typically make the hull somewhere between boxy and ovoid. It is common to note if the builder hollowed out a low amount of rock, as many shipyards will buffer the hull with extra structure and armour.

It is technically possible to move these hulls through air without destroying them but only at low speeds within extremely controlled environments with no wind or weather at all, such as within a highport's hangar.

ARMOUR TECHNOLOGIES

Improved technologies directly impact the materials available to construct spacecraft hulls. Some break this down for each Tech Level but it is more useful to consider broad ranges, within which high or low technology versions can be considered advanced or prototype forms of the main technology. Even on ships with hulls thin enough that they are not considered 'armoured', these materials provide basic protection against the rigours of space travel.

In each case, where windows are used in place of external cameras feeding viewscreens, there are transparent options of comparable strength. These are usually slightly weaker, so these portions of the hull are built thicker. Entirely transparent hulls are very rare for multiple reasons, primarily that the sensor nodes and jump emitters that must cover the hull would prevent perfect transparency. There have been enough comparisons made to inhabited spaceborne greenhouses to curb most efforts to create such a hull.

METALS: CIRCA TL7

Prior to the utilisation of crystaliron, the most useful materials for armour are raw elemental material, alloys or composites. This goes back to TL1 and is why most primitive civilisations have a 'bronze age', 'iron age' and so forth. Each metal that replaces the previous age is stronger and more durable. By the point that spaceflight becomes practical at TL6, electrically extracted aluminium is available, commonly replaced by steel or titanium alloys at TL7 and carbon fibre laminates at TL8.

CRYSTALIRON: CIRCA TL10

Synthetic crystal production, initially created to make artificial gems such as sapphires and diamonds in industrially useful sizes and shapes, eventually becomes able to grow perfect metals. Entire slabs of armour can be single crystals of iron interspersed with precisely positioned impurities, creating a material without any internal structural weakness. More critical to the practical adoption of crystaliron are the crystal growth and shaping tools to repair such armour, at shipyards if not in the field, after inevitable micrometeorite damage, deformation from the heat of atmospheric entry, and other wear. Some divide crystaliron into grades: 'dense' at TL10, crystaliron proper at TL11 and composites at TL12.

BONDED SUPERDENSE: CIRCA TL14

Collapsing the molecular structure of iron produces a material completely unknown to nature, outside of degenerate stars such as white dwarfs and neutron stars. This 'superdense' often sees use in buildings before vehicles and one of the Third Imperium's earliest uses was making hard-to-forge currency in a project named 'gravcoins', an evolution of which is still in the design of modern Imperial Credits. Bonded superdense has its electron bonds reinforced by electric currents and nuclear dampers in a refinement to the gravitic forge. As with other armour technologies, this is divided into grades: lite metal at TL13, superdense proper at TL14 and vlite metal – short for 'very light metal' – at TL15.

That is as good as it gets for most ships, although there are prototypes of a refinement to the superdense bonding process that seems likely to become the standard for TL16 armour. This is referred to as 'molecular bonded' or 'hullmetal' armour.

COATINGS

Although many hulls utilise some form of decoration, such as paint at lower TLs, with anodised metals and holographic displays becoming available later, coatings refers to those that optimise aspects of the ship to better serve its intended role. Most of these options are mutually exclusive.

Reflec coatings help protect a ship by reflecting light and heat. This gives the ship added protection against laser weapons, which are one of the more common forms of spacecraft armament. However, this is both an expensive modification and can hamper a ship's stealth, as the same reflective properties that defend against laser weapons make the ship far more visible to most forms of spacecraft sensor. Although perfect stealth is impossible, lower detectability can still buy valuable time to evade a pursuer. As a result, most ships will favour sandcaster batteries to defend against lasers, as they are cheaper and more versatile. See page 103 for details on sandcasters.

Similarly, a 'slick' coating can keep the enemy from using tractors and pressors to pull or push the ship. The idea originally started from people coating a wall or piece of machinery with a coating of oil so any grappling hooks, ropes or chains would slip off. The modern version for starships involves a coating of gravitic circuitry that provides the same kind of protection making tractors and pressors, detailed on page 105, slip off the hull. This is especially helpful where piracy is prevalent, to keep traders from being grabbed and their cargoes plundered. However, where piracy is prevalent, legal shipyards may instead stop selling slick coating to help law enforcement catch pirate ships more easily.

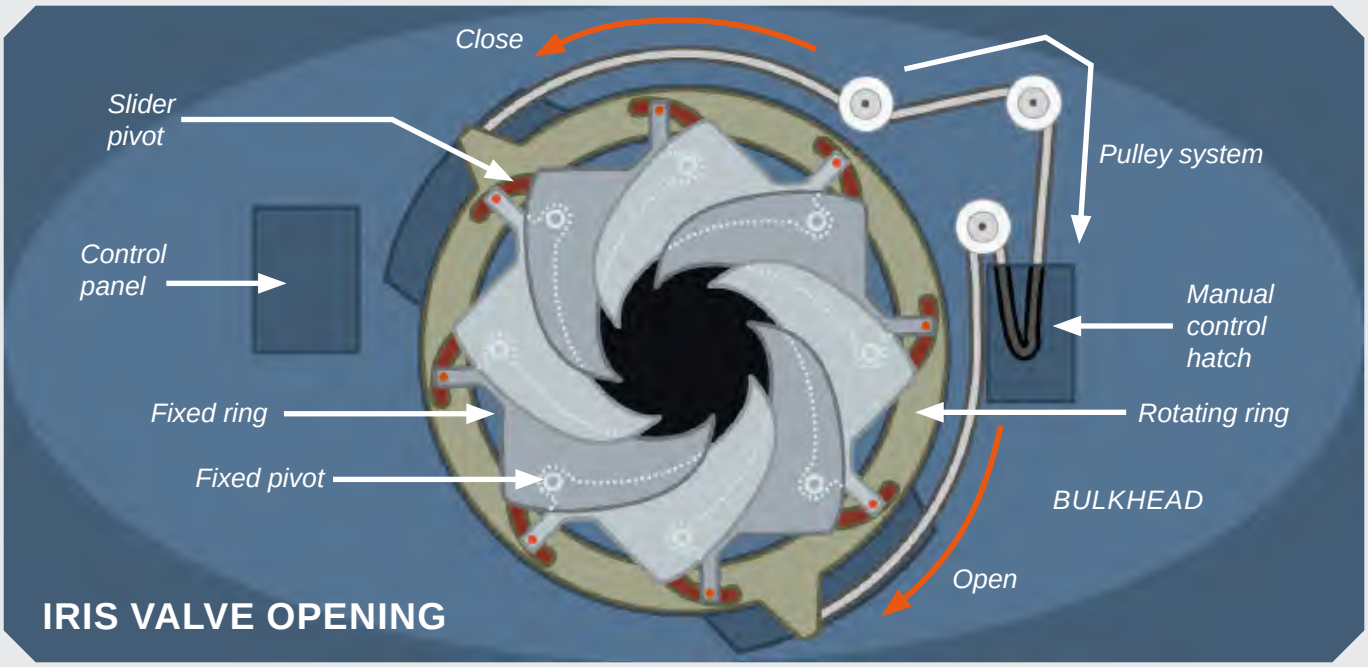
Solar coatings are little more than an outer layer of solar panels, usually serving as backups for the primary power plant, sometimes replacing it on space stations. Unlike deployable solar panels, they are conformal to a ship's hull and cannot retract, with all the drawbacks that implies. While sometimes shiny like reflec coatings, they do not offer the same anti-laser benefits. Ships with black globe generators, as described on page 106, sometimes use solar coatings, especially useful while drifting.

An 'ablat' coating is designed to burn off the ship, keeping the underlayers protected, meaning it must be reapplied regularly. While many believe that one could just keep stacking layer upon layer of ablat on the hull, even measuring a given level of effectiveness and remaining strength in multiples of a standard reference coating, an ablat coating is only one layer. Multiple layers of the same material either fail to adhere or cause the undercoating to become weakened and flake easier. How long this one layer can take the heat before it burns off depends on the components, which improve by Tech Level as better materials are developed.

'Anti-layers' specialise in protection from blasts, electromagnetic pulses and kinetic impacts. Non-ablative heat shielding is an early form of this, necessary for spacecraft without manoeuvre drives to safely enter atmospheres. By far the most common anti-layer is 'anti-rad', better known as radiation protection. Basic radiation protection is standard on most ships. Protection against weapons specifically designed to overwhelm with radiation is another matter, but ships can be built with extra shielding. Even when the entire hull does not have this coating, any ship weapon that fires significant amounts of radiation will have shielding around the weapon's mount, so that firing it does not harm the crew.

Less often seen are options for camouflage. While light emitting diodes and programmable paints can change the colour scheme of a ship, holographic hulls take it a step further, able to simulate battle damage or slightly different shapes. Going even further, extending beyond the realm of mere coatings, a hull can be built to shapeshift, acquiring the silhouette of another ship of the same tonnage. These ships tend to have electronics to give off emissions similar to the ship they are pretending to be. This is useful for fitting odd shapes of cargo, such as the *Nishemani* pirate ship that was built to envelop disabled 100 ton ships, regardless of its prey's exact dimensions.

Ships with an emphasis on stealth use a polarised coating that can switch on or off to absorb or deflect sensors. This expensive coating is popular among those wanting to hide their ship's presence, such as naval scouts or commerce raiders, not to mention corsairs. Some pirates claim the cost for this coating pushes them into a life of piracy to pay for it, while shipyards refute this claim, stating that most ship owners who are interested in this coating were already heading for questionable business practices. Blockade runners and smugglers favour stealth coatings.



INTERNAL TRANSIT

Corridors are as old as caves. Doors are almost as ancient. Sliding doors are more common than swinging on ships, as the latter require space to be kept clear, while the former are easier to open or close against a pressure differential. However, neither is as easy to make airtight nor as compact as the iris valve, so these are found anywhere where it is necessary to stop changes in atmosphere. As they are harder to bypass than doors, they have also become standard for security-conscious thresholds, such as bridge entrances. Dents or foreign objects that keep an individual plate of an iris valve from moving only stop that plate, allowing the rest to slide. These tend only to prevent full opening, not full closing, so anyone who wishes to damage an iris valve to force it open is better off breaking a plate. All doors aboard a typical ship, iris valves included, are motorised, opening and closing either under control of the ship upon detecting an authorised person or from a nearby control panel. Manual backups in case of power loss are usually present, save for the most secure of doors such as airlocks.

Another consideration is corridors, sometimes known as passageways. As there is only so much space inside a ship, most of which is given to various important systems, space for accessways is always at a premium. Corridors must be carefully laid out if they are to connect everything, rather than just jam room next to room and force people to tromp through the engineering space to go from the bridge to the commons. Cargo bays are notoriously prone to this sort of misuse, as most plans show them empty and they are rarely completely filled, leading to problems when the ship does take on all the cargo it can fit. Some large ships feature moving corridors, replacing sections of floor with conveyor belts to move people along a long, straight corridor but on small ships this is impractical.

Handholds or other protrusions line these corridors on ships or sections of ships designed without gravity. On ships with gravity these may still be present but usually tucked away so as not to impede movement, automatically emerging should gravity fail. Groups of handholds are independently powered by a fusion cell (see Power Cells on page 21), so this mechanism will work even if the ship suffers extensive damage. Handholds can also be found on the hull exterior, although are rarely retractable on unstreamlined spacecraft.

Trains and other internal mass transit options are only practical for large structures in space, well beyond the scope of this book. Even many large freighters and military capital ships are too small. Anything large enough to justify extensive internal mass transit is not so much a ship as a habitat, potentially an outpost or a colony. Some single-use colony ships, designed to be disassembled at their destination, have internal mass transit designed for expansion upon turning the ship into the colony's initial infrastructure.

UNRESPONSIVE DOORS

If a door will not open when you think it should, first make sure it would be safe for you to go through the door. If you do not have a vacc suit on and this is an airlock or leading to a damaged section of the ship, the door may be trying to save your life by not opening. If your ship uses access control devices, verify that you have yours and that it is operational. Should your ship use biometrics, check you are clean: grease, lubrication oil or carbon dust can obscure facial features and fingerprints. Many times, it is easier to check if there is another usable passage.

For an iris valve, find the iris crank opener that should be stored next to the valve, probably under the intercom terminal. Insert it into the slot at the corner of the door and turn it counterclockwise. If the iris valve begins to open, continue until you hear it latch, then remove the opener. Do not step through an unlatched iris valve unless in an extreme emergency. If it does not rotate, the door is bolted or jammed. Beating on the plates with the iris crank opener should be audible on the far side and attract attention if there is anyone beyond.

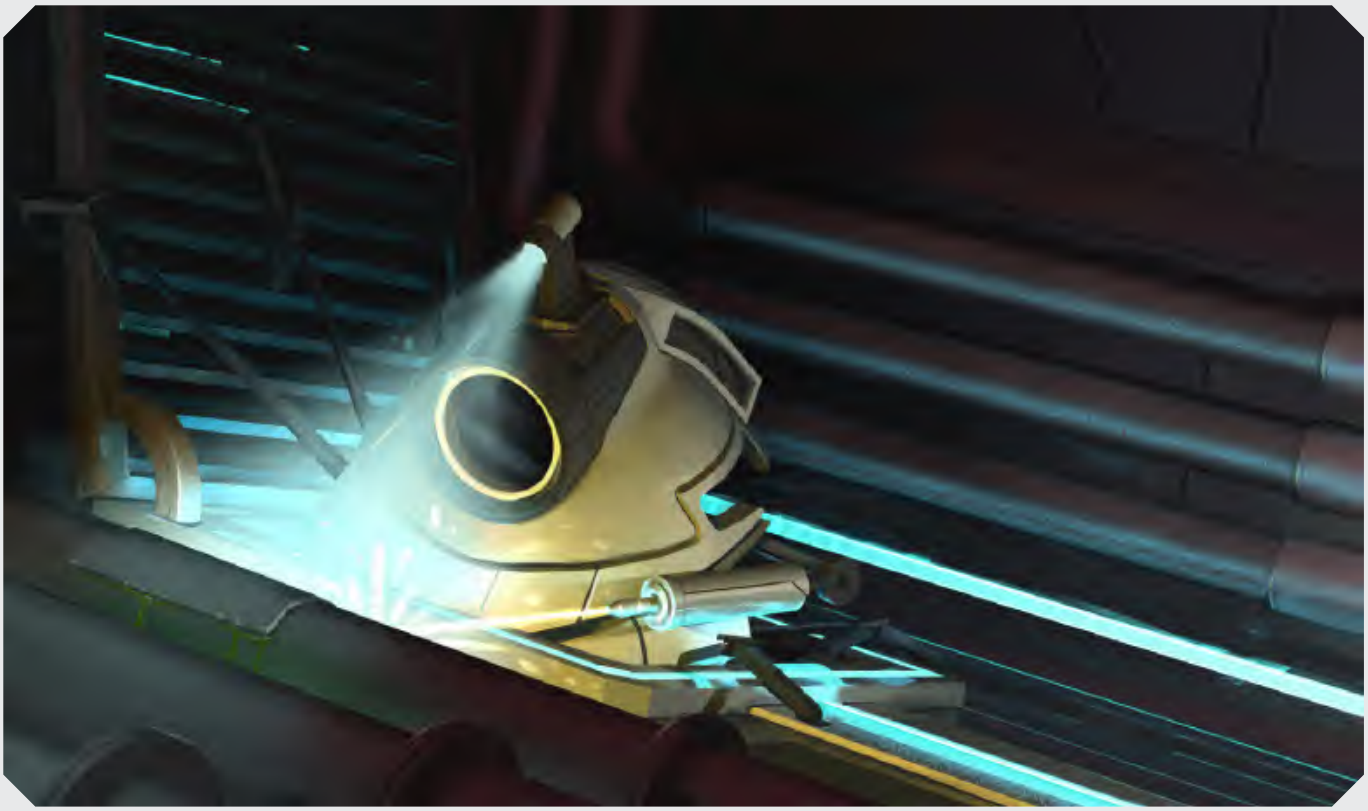
If the above does not work, use the ship's internal comm network to call the bridge for help. All areas that can be locked off have a minimum of one fixed mount comm nearby. Should that fail, this is a potential emergency and more extreme measures such as deconstructing the door are warranted. You may be being trained by your crew to deal with emergencies; if so, treat it as a real emergency.

CRAWLSPACES

Although the inner and outer hulls of a ship receive the most attention, there is a region between them that deserves special mention. Found directly beneath the outer hull, between bulkheads of the inner hull and decks, a ship's crawlspaces act as damage buffers and cable runs. These are rarely marked on formal deckplans, as most of a ship's crew will never need to access them. They do not exist inside all walls; many are too thin, while others are solid. Builders construct them with an eye toward thermal and/or sonic isolation of the adjacent spaces. The crawlspace is often used for routing pipes and cables.

The crawlspace exists outside of the life support systems within the inner hull. Although typically airtight, the crawlspace is invariably at the extremes of the temperature range and may even lack artificial gravity. Some may think to don a vacc suit before entering the crawlspace and this is the recommended procedure, particularly while performing damage control. However, this can make an already cramped environment near-impossible to navigate. Even if the engineer foregoes a vacc suit to manoeuvre more easily, a respirator should be worn as these spaces can easily develop a hostile environment due to the lack of fans or purification equipment. They are more at risk of sudden depressurisation, even if not normally kept depressurised. For these reasons, maintenance on systems within the crawlspace is often left to the most junior engineer if it cannot be done via drone. Anyone going into a crawlspace should ensure that someone is on standby before entering – becoming trapped there is a poor way to die.

Crawlspaces have become infamous for many of these reasons, although enterprising engineers can make good use of them. Especially on small ships, they allow an engineer to access almost any point on the ship with or without permission, as most crawlspace access is through direct removal of hull panels. This is slow but effective. Many an engineer's wrench suddenly cracking across their head has foiled a would-be boarder. Their infamy leads most to ignore them. Smugglers try to take advantage of this, storing goods several metres clear of any access hatches, although starport inspectors looking for contraband are quite familiar with this trick, bringing their own drones to search these places. This can allow stowaways to hide aboard ship, assuming the engineer is lax in their maintenance, although anyone considering this should be careful to bring a good respirator or leave a hull panel partially open. Refer to page 62 for more detail about stowaways.



POWER SYSTEMS

After the hull, power is the most vital system on any ship. Without it, a ship is an inert mass drifting through space, unable to do anything. The excessive demands of the manoeuvre and jump drives necessitate the generation of large amounts of power. With excess energy available, standard life support systems have adapted to use it and thereby minimise their mass consumption, greatly extending ship endurance.

As with the rest of the book, the technical explanations in this chapter are merely mostly accurate summaries. Those wishing to construct their own power plants should consult more specialised manuals and avail themselves of expert assistance. The best place to experiment and build one's first unit is in the classroom, or at least under close supervision of tutorial software written for this exact purpose and tested to resolve common misunderstandings.

COMMON POWER SYSTEMS

Fusion power plants are the dominant standard for spacecraft, with solar power the second most common method, as these require minimal amounts of mass to function. This limitation is one of the biggest differences from planetary power plants, where mass is supplied more easily. These are not the only options but most starship crew, even non-engineers, should at minimum know the basics of these two processes.

While large, older or alien ships may have more bespoke designs, nearly all modern ships manufactured within the Third Imperium use some evolution of the Fusion+ process introduced by Cleon I. Aside from using the same liquid hydrogen fuel as the jump drive, making storage simpler, the main practical impact is that any given power plant engineer has worked on something similar previously. This makes its impact easy to underestimate. Before Fusion+, fusion plants from Vland and Terra could be as different from each other as they were to fission.

Fusion+ is associated with the Third Imperium for historical reasons, as many took the technology and distributed, copied or independently reinvented it throughout Charted Space. Fusion+ was invented in -28 by Cleon's cousin, Aldin Zhunastu, while employed by Zhunastu Industrial Laboratories, which was the part of the company that Cleon had a controlling interest in. Historical reports are muddied as to exactly how much involvement Cleon had in the actual creation and early development but it is clear that the commercial success of Fusion+ starting in -10 was instrumental to the rise of Cleon's fortunes and the founding of the Third Imperium. This strong association is a large part of the reason why advanced fusion processes developed in the Third Imperium continue to be called 'an evolution of Fusion+' rather than a completely new process, so long as they are broadly similar to previous models.

The basic process behind Fusion+ is as follows:

1. Heat hydrogen atoms to a plasma state, contained by an array of magnetic and gravitic pressors, so they break into protons and electrons.
2. Use nuclear dampers to stimulate beta decay, turning half of the protons into neutrons, releasing neutrinos that escape and positrons that annihilate with electrons.
3. Ram lone protons into neutrons, turning them into deuterium nuclei and releasing energy as photons.
4. Use gravitic separation to separate the deuterium nuclei from the lone protons and neutrons.
5. Ram them into more neutrons, turning them into tritium nuclei and releasing energy as photons.
6. Use gravitic separation to separate the tritium nuclei from the deuterium nuclei and neutrons.
7. Ram them into protons, turning them into helium nuclei and releasing energy as photons.
8. Use gravitic separation to separate the helium nuclei from the tritium nuclei and protons.
9. Let the helium nuclei cool down enough to accept their electrons back.
10. Vent the helium.

As should be readily apparent, this process is highly dependent on the availability of gravitics and nuclear dampers, which is why even inefficient prototypes do not appear before TL9. Sensor operators across Charted Space are familiar with escaping neutrinos and a common way to scan for an operating fusion power plant is to look for something giving off lots of neutrinos.

This process requires active regulation. If the fuel shuts off, the reactor is cracked and plasma escapes, the nuclear dampers shut down so protons resume repelling each other and no more neutrons are manufactured, or any other failure scenarios occur, the process ceases. There is no significant explosion from vented plasma. Even deliberate sabotage, unless it directly damages the reactor, leaves most parts in working order.

Any fusion power plant includes a rechargeable power storage block to provide power to heat hydrogen and run the operation until it starts generating power, referred to as a 'black start'. By far the most common mistake operators make is to tap this block for any other purpose. In an emergency, if the reaction is generating enough power that this will be recharged and a momentary burst of power will help, this is forgivable. In most cases, those conditions are unmet, so diverting this power either is useless or makes things worse. Fusion power plants have safeguards to prevent draining this block when the plant is shut down, requiring deliberate effort to bypass.

The main problem with fusion reactions is that they need an extremely high energy density to achieve temperatures in the hundreds of millions of degrees. This tends to have deleterious effects on both matter and the reaction itself. Without gravitics and nuclear dampers, the only way to reach the desired energy density is with high-energy lasers or magnetic compaction, and the only methods to keep the plasma confined are magnetic fields and wishful thinking. This requires more energy to control. Due to these factors, the lowest TL advanced fusion reactors are heavy and bulky, unsuitable for starship use. Improper maintenance can cause a high TL reactor to revert to these processes and need shielding installed.

Gravitic containment is helpful in preventing the reaction from touching the reactor, which would shut down the plant by supercooling the reacting plasma. Nuclear dampers allow lowering the interatomic binding forces between particles. This in turn allows fusion reaction pathways to take place at lower temperatures at a corresponding loss in efficiency. A modern fusion reactor is hot but not at star-core temperatures, many topping out at tens of thousands to a few million degrees. The limiting factor is the physical structure of the reaction chamber, with higher TL chambers more resistant to thermal flux, allowing a higher reaction temperature with less required damping as well as more useful extraction of power.

Solar power is much less varied. When strong light strikes a material manufactured with carefully controlled impurities, it dislodges electrons across part of a circuit. If both sides of this material are properly wired, the electrons have an easier time returning to where they came from by following the wires rather than crossing back through the material. This forms a current that can be tapped for electrical power. The primary variance is in the exact materials used which affect the wavelengths of light absorbed, amount of voltage generated per square metre, useful lifespan and more. The light of a nearby star constitutes a strong light, although small voltages can be generated from typical indoor lights. Distant starlight or the light of jumpspace

REACTOR PROTOCOL

There are those who say that if you are not scared of nuclear processes, you do not know them well enough to maintain a fission or fusion reactor. This is false knowledge. To the uninitiated, 'be scared' sounds like competent reactor technicians must be constantly running around in a state of panic, which would be the opposite of useful. 'Be careful' is much more appropriate.

Study the processes. Practise in safe simulations so that when you inevitably mess up, you survive and learn. Memorise what to do, so you will not spend time you will not have during emergencies to look things up. Only try the real thing once you can handle simulations by rote. Use automation when available; no one will be impressed that you can do everything robots do but those who know how to responsibly oversee fission and fusion power plants may be alarmed if you attempt to do a robot's work for no good reason.

For instance, the most common startup problems of fusion power plants can be diagnosed mostly by paying attention to the plant's temperature, pressure, neutrino flux and power sensors, readouts of which are visible on the default display of almost any console configured to operate a fusion power plant.

- Failure to reach operating temperature, as detected by thermal sensors in the chamber, without an increase in pressure is usually due to insufficient available power supply during pre-heat. Verify that the power storage block has sufficient available power for startup and check its connection to the reactor.
    - It is not necessary to abort startup while troubleshooting this issue while at a port if startup power can be provided, athough not all ports can: Class E and X ports have nothing to generate power, while a Class A port might run into political or bureaucratic troubles with providing power to a docked ship.
    - If this occurs where there is no backup to the power storage block, immediately shut off power output from the power plant until the block is fully charged. This should not be an issue, as a power plant should not be providing power while starting up. Do not wait for confirmation, as exhausting a ship's power with a shutdown reactor in deep space is a one-way ticket to becoming stranded at worst or deeply embarrassed at best.
- Failure to reach operating temperature but achieving a significant increase in pressure is evidence of a gravitic pressor misalignment. Shut down the pre-heat and troubleshoot the gravitics, starting by running them section-by-section, and comparing field output strength. Any section with a different strength needs to be replaced. In extreme emergencies this can be overridden but it will permanently damage the reactor within minutes.
- Exceeding operating temperature without detectable neutrino flux is evidence of a failure of the nuclear dampers. Shut the reactor down and commence troubleshooting. Since a lack of neutron manufacture means no neutrons to fuse with, this cannot be overridden except in cases of partial failure and is inadvisable for the same reasons as above.
- Reaching fusion temperature with neutrinos detected but the ship's power still discharging is evidence of a failure in the electrical conversion machinery. Shutdown is recommended but not required, as the plant can remain operational at minimum power if there is another source of electrical power available. If used, ensure the power storage block does not remain drained for long.

are insufficient to generate significant power, so for starships this is a backup option for in-system operations at most.

Fusion power plants have a maximum recommended rate of power generation. Much like most vehicles have a maximum recommended speed but are capable of going faster for brief periods, fusion power plants can be 'overclocked' for short periods, generating more power. This does not significantly increase fuel consumption but does increase wear and tear on the plant, for instance by reducing pressor strength to allow a greater volume of plasma, which risks some plasma reaching and damaging the reactor wall.

ELECTRICAL POWER CONVERSION

Most shipboard systems run off electricity rather than direct thermal input or radiation flux. Therefore, the power plant's output must be converted into electricity. Two common methods of accomplishing this are direct radiation conversion and closed-cycle turbines.

Radiation conversion is performed through the use of a sphere of extremely high-purity photovoltaics inside the reaction chamber, kept separate by gravitics pressing the plasma away, effectively forming an invisible wall. These photovoltaics are optimised for high-energy photon input and have an extremely high energy capture efficiency at 99.8% or greater when initially installed. These are optimised for far greater energy intensities than experienced by solar panels facing a star at much further distances than in a fusion power plant. Using them in solar panels would not significantly increase output but would drastically increase expense. These photovoltaics will degrade over time and not replacing ageing sections during annual maintenance is the primary reason why older reactors fail. The minimum recommended collection efficiency from this layer is 99%, as less indicates a chance of failure under normal operating conditions. The capture sphere is solid-state and does not require attention from engineers outside of maintenance.

Closed-cycle turbines generate electricity through indirect thermal generation methods, boiling a working fluid via core heat, running it through turbines, re-cooling the fluid and repeating the cycle indefinitely. This is a common primary method in chemical and fission power plants and a required secondary method in fusion plants, serving to carry away the 0.2–1% of waste heat from the conversion sphere and preventing thermal degradation of the photovoltaics.

The total amount of electrical power generated by a starship is not that high. For the three ships featured in the Ship Walkthrough chapter, total electrical power generation comes to about a few hundred megawatts. Some non-engineers may wonder why these numbers are so low when fusion could theoretically output immense amounts of energy. The reasons for that are threefold.

Firstly, there are technical limitations. It is possible to set dampers to a lower power to harvest more energy. This is rarely desirable as the reactor's turbine coolers will not be able to remove all waste heat, the capture sphere will begin to degrade as it heats up and the overall plant capacity will decrease. Higher sustained plant outputs are achievable through more resistant reaction chambers developed at higher TLs.

Secondly, good engineering respects economic efficiency. Starships of these sizes need a few hundred megawatts to use drives at 1G, jump, and maintain life support. Unless they have a specific reason to need more, they do not have more. For example, the *Animal*'s occasional paramilitary uses need it to employ the m-drive at full power while the j-drive prepares a hasty exit. It carries environmentally sensitive cargo that needs full life support constantly, so it needs enough power to run these simultaneously. The *Empress Marava* encounters such situations rarely if at all, so it does not have enough power generation to handle this scenario. Good engineering practices do not add expensive capacity 'just because' and buyers do not wish to pay for capability they do not need.

Finally, hundreds of megawatts is not a low quantity. A landed *Empress Marava* can easily power thousands of households, tens of thousands on a mid-TL world. While lighting up a nation is out of the question, lighting up a large town or small city is very doable.

Similar to how 'resource units' measure availability of wealth and other factors, as opposed to only measuring raw currency in Megacredits, it is common to measure power on a ship by 'power points' that factor in power availability and other elements, rather than just measuring raw power in megawatts. Just like how fortunes measured in resource units contain Megacredits of wealth, a ship's power points contain many megawatts but there is no direct conversion. To put it into numbers and say that X power points are always Y megawatts is incorrect.

POWER CELLS

Where power is generated, there is often a need to store it. Starships are no exception. Whether for an emergency backup or to handle surges in demand, no shipboard power system would be complete without banks of power cells. These come in a wide variety of forms, starting with chemical storage at lower TLs, up to dedicated ultracapacitor banks.

By raw capacity, most starship jump drives provide the most energy storage of any system on the ship when not charging up for jump entry. A jump drive must store and quickly shunt a large amount of energy in a very short period of time. This is done by banks of ultracapacitors, typically zuchai crystals. Using this for long-term energy storage places stress on the system, with potential consequences up to and including explosive release that destroys the ship, so it is recommended to 'borrow' this storage capacity for less than an hour at a time.

How much energy storage ships have varies. Some have an upgraded capacitor bank allowing them to feed in power over time, then discharge from the capacitor bank into the jump drive at the moment of jump, rather than relying on main power from the power plant. Other designers, particularly of military ships, build a power plant that can fully power manoeuvre and jump drive as well as basic ship systems at the same time. This might seem like overkill but does keep the ship from being stranded by damage that degrades but does not destroy the power plant.

The next most common type of energy cell is the fusion cell, a miniature fusion reactor which is less efficient than larger systems but far more portable. A typical fusion cell consists of a vacuum flask for a fuel tank, a tiny fusion chamber rarely more than a few centimetres across, and an ultracapacitor bank. When the ultracapacitors are mostly discharged, the chamber draws a small amount of fuel and runs a brief fusion cycle initiated using the remaining charge, resulting in a pulse of electricity that the ultracapacitors soak up, the entire recharge operation taking less than a second. The ultracapacitors then mete out power to whatever is plugged into the fusion cell until they are mostly discharged once more. A fusion cell's limited ability to accept power from other systems makes it more refuellable than rechargeable, although its ultracapacitors help smooth power spikes. Maximum output is less than a proper fusion reactor, however. Anything needing maximum output power or more is better off running it from a vehicular or ship power plant, despite countless attempts to jury rig a solution from many fusion cells.

The use of small fusion cells dates to the original Fusion+ design, where reactors large enough for starships were scaled up cells or arrays of cells. Even today, most large plants are simply arrays of cells, rather than a single large unit. The biggest change is the fuel as small cells used deuterium manufactured by larger fusion plants, following the steps listed before but stopping when deuterium was extracted. The miniaturisation of nuclear dampers allowed modern fusion cells to use liquid hydrogen, making refuelling much simpler.

So long as it avoids damage and extreme environments, the lifespan of a fusion cell is limited by two factors. First, the fuel tank is constructed to insulate its contents as much as possible, only connected and thus transmitting heat to the rest of the device through the input/output valve that draws tiny amounts of fuel to cool itself. This is why fusion cells cannot hold their full capacity 'on the shelf' indefinitely; most will be at over 90% after a few months of storage. Second, ultracapacitors have a limited lifetime, being good for millions of charge/discharge cycles, while a fusion cell typically goes through thousands between refuelling. Since refuelling is the only external maintenance action performed, this leads to a perception that the fuel cell fails after merely thousands of 'recharges'. Some models can regenerate ultracapacitors at the cost of fuel, providing an indefinite lifespan, and most of those automatically do so during refuelling if the cell has fallen under 99% peak efficiency. There have been reports of fusion cells left alone for over 100 years, their fuel long since drained, retaining enough charge to run another fusion cycle once refuelled.

After fusion cells, superconducting batteries are the next most common type of energy cell. These are brutally simple; electron currents go in and come out via control circuitry in a manner analogous to compressing and releasing gas, whilst indefinitely circling a loop of superconductive material. These materials can only store a limited charge before the electric fields generated by the electrons racing around alter their material properties and cause them to develop resistance. That causes the remaining electrons to transfer their energy into the material as heat, causing more resistance until the entire work melts down. This radiates heat to nearby superconducting loops that likewise melt down and turn their stored energy into heat, in a chain reaction that is usually catastrophic for the ship and anyone aboard. It is among an engineer's many duties to keep the stored energy within rated limits to stop a chain reaction from happening.

At lower TLs where superconducting batteries are not available, reversible electrolysis fuel cells are used instead. Available from late TL8, these pass hydrogen and oxygen through a membrane to extract water and electrical power. The process can be reversed when there is excess power available. Conversion efficiency is high but not 100%, thus why superconducting batteries are preferred at higher TLs. These designs are usually sealed, closed-cycle devices where the hydrogen, oxygen and water are stored in dedicated tanks attached to the fuel cells, although some designs share these three components with the ship's general supply. Fuel cells are less prone to sudden overheating or explosion so long as the membranes and tanks do not leak. When they do, it is recommended to discharge the leaking cell as soon as possible. Electricity can be stored elsewhere and leaking water is famously much harder to ignite than leaking hydrogen and oxygen.

FUSION FUEL TANKS

Fuel tanks are one of the biggest systems in most starships, requiring 10% of the ship's volume per parsec of range. The portion needed to run a typical fusion power plant is a small fraction of that needed for jumps but since both systems take liquid hydrogen, the same fuel tank system is used. This affords the ship much longer endurance between refuelling if it does not maximise the use of its jump drive, although the ship can risk becoming stranded if there is too little fuel left to jump and no means of refuelling.

Given that they take so much volume and sometimes spend long periods empty, designers developed a variety of alternative fuel tanks, such as high-purity tanks often found on starports. Some collapse to provide extra cargo volume when not carrying fuel. Some are mounted externally, carrying one jump's worth of fuel and dropped just as the jump field is forming.

Keeping fuel tanks in working order is vital to the power systems of the ship. A leaking tank causes problems, both from the spill and running out of fuel sooner than expected. Ships have been rendered dead in space from a relatively small fuel leak that no one did anything about.

Many ship designers consider fuel storage filler space, breaking it into areas spanning several decks in odd shapes to fill volumes between the hull's outer skin and the often-boxy rooms and corridors of crew-accessible space. This is especially true in streamlined ships, a practice dating to pre-spaceflight aircraft, which often store their fuel in their wings as those are too thin for anyone to sensibly enter. Thus, most fuel tanks are custom-designed for the layout of their ship and firmly embedded as part of the hull.

Because of this, fuel tank maintenance involves assembling patches from standard materials and parts more than replacing entire tanks. There is normally one or more service entrances per tank for a technician or drone to access it. If a fuel tank must be entered while

partially full, a temporary airlock is deployed around the service entrance, then fuel tank compartments are drained and filled one-by-one to allow the technician or drone to move through them without being directly exposed to the fuel. A completely full tank must be partially drained first, such as by the leak that needs repairing in the first place. Even hostile environment vacc suits do not protect from the extreme cold temperatures and high pressures of liquid hydrogen.

The tank compartments have cryogenic insulation to keep the liquid hydrogen cool, commonly using a simple double hull for vacuum insulation. This cryogenic lining is covered in a self-sealing non-hydrogen-reactable coating that will react to stress and close punctures automatically. When an area needs replacement, first the exact area to be replaced must be designated, typically by drawing a boundary on a virtual model of the fuel tank. Using this model, a piece of the exact shape and size required is manufactured and then put into place after the old section is cut away. A coating is applied to the seam between the new piece and the surrounding fuel tank, which is traditionally given one full day to bond before being tested to make sure it will hold. While higher TL materials can set faster, taking less than a day is widely seen as endangering the ship by not allowing the tank coating to fully bond, although it is understandable during emergency repairs.

Pipes carry liquid hydrogen into and out of the fuel tanks. In addition to being insulated similarly to the tanks, they incorporate gravitics to help push and pull fuel. Articulated baffles inside the tanks further assist flow, preventing sloshing and backwash. These baffles can divide the tank into multiple compartments, helpful when unrefined fuel is being refined, allowing a ship to quickly scoop fuel from a world's surface or gas giant's atmosphere and refine it one compartment at a time en route to the jump limit. This internal division is useful to limit leaks should the tanks be breached, similar to compartmentalisation of the hull.

FUEL SCOOPING AND PROCESSING

Fuel scoops refer to systems that quickly mine the environment around a ship for fuel. There are three types of fuel scoops. Atmosphere-type scoops quickly filter hydrogen from hydrogen-rich atmospheres such as on most gas giants. Fluid- or water-type scoops filter out water from a potentially mixed liquid, most often sea water, then electrolyse hydrogen from it. Ice-type carves chunks of ice out of comets, heating the ice to its melting point then feeds melted water into the fluid-type processor. The melting is done inside a miniature airlock to add pressure, as water ice sublimates to gas if sufficiently heated in a vacuum.

Most ships that have fuel scoops have all three but there are exceptions, so when posting to a new ship it is good to confirm which it has. The speed of scooping comes at the expense of impurities in the obtained resource, meaning that fuel scoops obtain unrefined fuel, which is problematic for jump drive use and, if used over long periods, can present maintenance headaches for fusion power plants and hydrogen-using reaction drives if not refined. Most ships with fuel scoops have a fuel processor that removes these impurities, turning unrefined fuel into refined fuel that presents no such troubles.

Fuel processing uses much the same heating and filtering processes described in Water Recirculation on page 30, along with gravitic density sorting similar to how a fusion power plant separates helium from hydrogen. Even on large ships, it is common for the same crew to maintain both fuel processors and water treatment facilities, using such similar skills and tools that the unwary can temporarily forget which system they are tending.

Scooping fuel goes much faster than processing fuel unless the fuel processor is far larger than it needs to be. It is common to scoop fuel quickly and then spend the entire trip to the jump location processing it, possibly even longer. Even without scooping, unrefined fuel is more widely available at ports than refined fuel is, leading many to view fuel processors as an investment.

It is technically possible to use atmosphere-type fuel scoops to skim hydrogen from a star, at rates akin to skimming from a gas giant. While this can be more convenient than hunting down cometary ice – let alone travelling to the Kuiper belt or Oort cloud – doing so entails all the predictable hazards of travelling close to a star, in particular requiring more heat and radiation shielding than most ships possess and as such is generally reserved for the desperate or foolhardy even on ships equipped to survive the process. The result should be considered unrefined fuel, although the usual contaminants – mostly helium – are different from those found in gas giant atmospheres.

Large ships may have scoops on subcraft rather than scooping fuel themselves – taking advantage of the square-cube law and allowing redundancy – but small ships do their own scooping. Scooping fuel can be one of the most challenging operations a pilot will perform, which means that large ships may have a

split between steady and reliable main pilots versus hotshot subcraft pilots, while small ships have those hotshots as their main pilots. While this stereotype is far from universally true, it does contribute to the lesser degree of service that small ships receive at certain starports. Some small ships only ever go from starport to starport, reserving their fuel scoops and processors for an emergency.

Ironically, this is part of the reason why unrefined fuel is more widely available at smaller ports – if almost all ships will only buy unrefined fuel, there is little market for a starport to run its own fuel purification. Still, having a fuel refinery is one of the requirements to be declared a Class A or B, and in some cases even Class C, starport. Larger ports more often service ships that only go from port to port and thus do without their own fuel processors to have more cargo and/or passenger space.

While fuel scooping and processing is standard practice for non-commercial ships, many traders or passenger liners prefer to buy their fuel at a port instead. There are three primary reasons for this, the first being time. Although fuel scooped from natural sources is 'free', it is a significant time investment; 2–4 hours to scoop and 24 to process is typical, compared to the 1-2 hours to refuel at a port. For most commercial ships, time is money. Second, some systems do not allow fuel scooping, out of environmental concern – particularly with oceanic refuelling – or a desire to control their revenue sources. Some systems seed CAPTOR (CAPtive TORpedo) mines within their oceans and gas giants to secure this restriction with lethal force. Finally, wilderness fuel scooping can be dangerous. Even without a port's interference, dangers such as turbulence from gas giants or local large fauna can kill a ship as surely as a torpedo strike. Commercial ships rarely see the risk as worth it compared to paying a few thousand extra Credits at a port.

A final word to the wise: Always run purchased fuel through the ship's purifiers, unless desperately short on time or lacking purifiers. If nothing else, test the fuel prior to addition. While there are tank sensors and filters available for feeding in unrefined fuel, most fuel systems bypass this for any fuel the crew tells it is refined, whether through controls or feeding via a separate port marked 'refined fuel'. This allows significantly faster fuel throughout, but any contaminants will go straight into the refined section and remain undetectable until mixed, contaminating tons of bad fuel before the crew can notice and reach the external cut-off. This will clog up internal piping and fuel intakes, crashing reactors, reaction drives and jump drives until the tanks are fully cleaned, a process that can take anywhere from hours to weeks.

There are anecdotes of starport crews across Charted Space dealing with corsairs or pirates who demanded fuel service by topping them up with a few tons of cement, animal slurry, or human waste from the port's septic tanks. While these appear to be mostly fictional, the fact remains that this is an efficient and cheap way to immobilise a small ship with an inattentive crew while disabling all non-battery-powered weaponry. It pays to be polite to the staff at a backwater Class C port one is obtaining 'refined' fuel from or, failing that, to check their work before trusting it.

Ramscoops or plasma scoops are essentially 'plasma-type' fuel scoops designed to obtain fuel from interplanetary and interstellar mediums. These require the ship to travel through large volumes of space to obtain significant fuel from the very thin material. Plasma-type scoops also work well harvesting coronal mass ejections, for those able to wait for them. These scoops are most often encountered on spacecraft intended to travel from star to star without jump drives.

LIFE SUPPORT

Every spacecraft, even shuttles that only travel between a world's surface and orbit, must provide certain minimum services to keep their crew and passengers alive and functional. Should any of these systems fail, the crew – and eventually the ship – will diminish. Even entirely robotic ships must make concessions to life support functions, such as scrubbing dust, shielding against radiation, and providing thermal regulation.

THE BASICS

The following systems are present on virtually all spacecraft. Even robotic spacecraft not designed to carry living beings have uses for most of these, in particular radiation protection. Artificial gravity, as detailed in the Gravitics chapter, is not technically part of the basics as a lack of gravity is less immediately fatal than a lack of air. Most spacecraft place internal artificial gravity controls with general environmental controls.

Although some elements of life support can be controlled by their occupants – with safeguards in place to prevent involuntary manslaughter – much of a ship's life support will be under centralised control. This is used to match a ship's overall environment, such as might be found in passageways or common areas, to a given world. When travelling from one world to another, as starships often do, the shipboard environment may be slowly changed from the origin world's environment to the destination's, giving time for passengers to acclimatise.

OXYGEN AND VENTILATION

The most well-known hazard of space is a lack of breathable air. Humans consume over half a kilolitre of oxygen per day, which at typical concentrations means going through about 11 kilolitres of air, assuming a standard nitrogen/oxygen mix, per day. A lack of oxygen will kill a typical adult human in about 7 minutes. These numbers are within a factor of 10 for most other known sophonts. Thus, oxygen circulation is of primary importance to life support.

Short-term air storage is not a major concern. Starships are highly buffered through large open spaces. It is theoretically possible for an *Empress Marava* with standard atmosphere mix, a full standard human crew, no passengers and an empty but pressurised cargo hold to take off, go through a jump and land with no functional air circulation. Attempting to do so would showcase the reason why starships have life support systems.

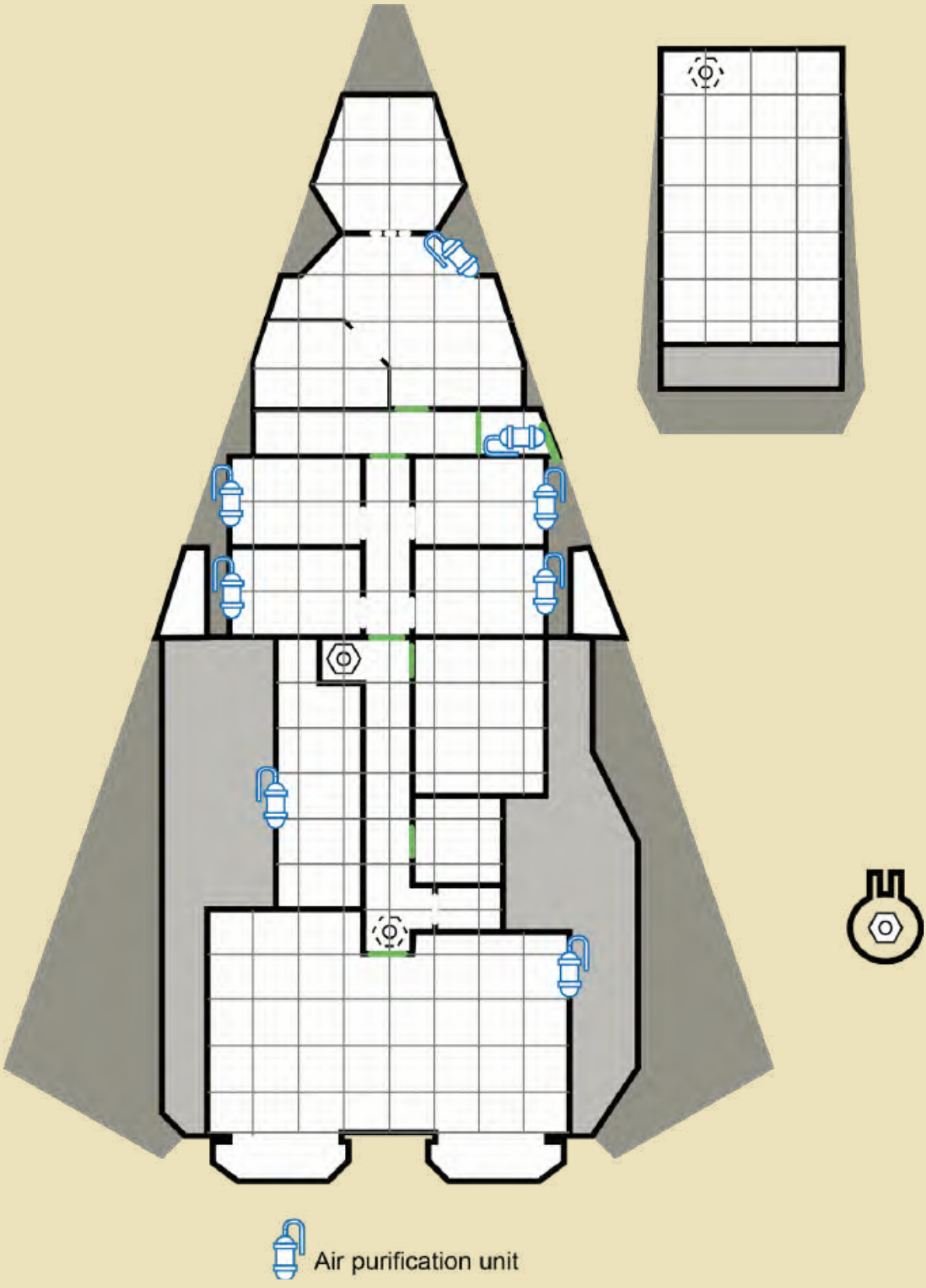
Given that six-person crew with no filtration and a 10-day transit from ground-to-ground, operating the ship from the cargo bay and ignoring all other life support needs for this example, oxygen content will drop by 10 percent, equivalent to almost a kilometre above sea level on a 1G surface gravity world with a standard atmosphere. This is manageable. What is less manageable is the carbon dioxide buildup. In short order, the air will begin to become stale and the partial pressure of CO_2 will begin to rise.

Ordinarily, starship air has a carbon dioxide concentration of less than a tenth of a percent. On average, humans breathe out a kilogram of CO_2 per day, less if doing nothing but lying in a bunk sleeping. That six-strong crew would generate 60 kilograms of CO_2, increasing its concentration to about five percent. This will cause headaches, dizziness, impaired judgement and possibly unconsciousness. It might go unnoticed as it would slowly take effect over the 10 days, although it would be immediately noticeable to anyone walking in from a room with fresh air. Should the CO_2 concentration rise to six percent, it would be lethal. Without ventilation fans or other air circulation, CO_2 will pool at low points in the ship's gravity, where it can easily exceed six percent concentration and risk killing anyone who walks in without holding their breath.

Those who find themselves in this situation are advised to break out the vacc suits and oxygen candles that are there precisely to keep this sort of emergency from getting worse.

In the interest of delaying such an emergency, one of the main things that a shipyard will check during maintenance is the air filtration system. On some ships, the number of dedicated sensors is higher on the ventilation system than the jump drive. While standard staterooms have the same equipment as the normal ship-wide ventilation, many luxury staterooms have

OXYGEN STORAGE ON BOARD THE SULEIMAN SCOUT COURIER



their own dedicated and improved ventilation system to give the highest quality of air, optimised minute-by-minute to the current activities of the occupants, such as giving more oxygen during exercise.

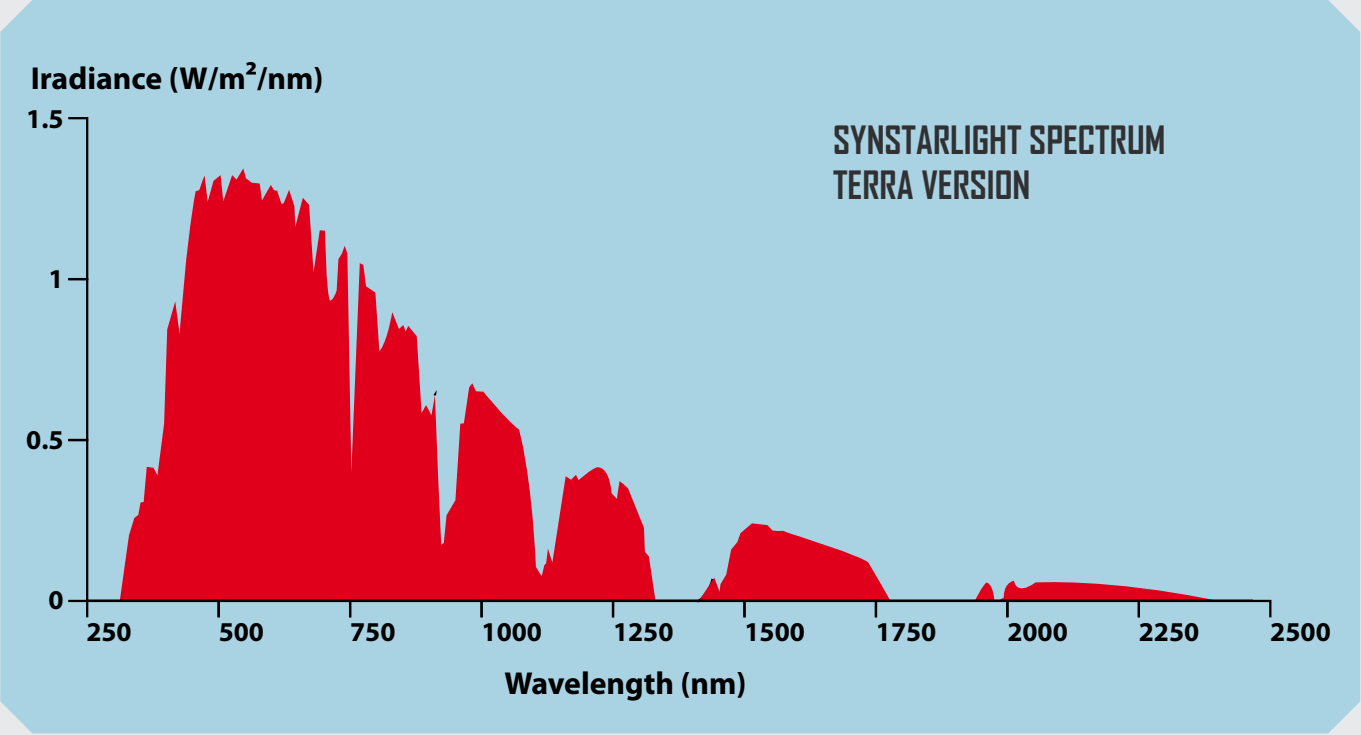
Designers distribute redundant air storage and treatment units across even small ships, in case one malfunctions. One per airlock, stateroom, engineering space, medical bay and bridge is standard, with some passenger-focussed ships adding one per common area. Ships with many rooms may share one unit per group of staterooms or equivalents such as brigs and barracks; one large air treatment unit for a block of brigs is common, both for efficiency and because it allows placement that does not require a maintenance technician to enter a cell to service the unit.

While all ships store air as a backup, particularly as part of airlock systems, most modern ships have what amounts to highly refined algae to break carbon dioxide into oxygen. As noted under Water Recirculation, 'reserve' oxygen is most often stored bound up into water. So long as power and water are provided and the algae kept safe, a ship can keep its crew breathing indefinitely. Oxygen storage for immediate use is primarily in high pressure tanks, with oxygen candles as a backup. Any ship burning oxygen candles can be considered to be using emergency supplies, as it implies a crisis no matter how the captain may try to spin the situation. Should this captain attempt to operate their ship without functional life support, they may be subject to spaceport regulations such as being unable to board passengers or not being permitted to take off at all. Vacc suits and rescue balls do not count as life support for this purpose.

More numerous than air filtration systems are the air circulation systems, microgravitic units that ensure air keeps flowing gently through vents. These are short-range unfocused tractors, sometimes supplemented by fans. Constant strong breezes would be an annoyance to most sophonts but pockets of unbreathable carbon dioxide floating around are invisible. Given the presence of artificial gravity, most ships use circulation designs that stem from pre-spaceflight mining technologies to deal with 'bad air', though needing far less power per volume served. More sophisticated ventilation, such as in luxury staterooms, actively scans the air to find and quickly remove unwanted contaminants. Some captains request specialised air circulation systems to be mounted behind the captain's chair so they can look impressive with a breeze blowing from behind, more often triggered by a subordinate or program monitoring the captain's communications than by a button push or other explicit action on the captain's part. Exercise rooms make more common use of this directional ventilation capability, to cool the room's users and remove odours.

LIGHTS

Keeping the darkness of space away is vital to avoid accidents. Areas the crew traverses daily can seem very different when unlit. External windows only provide



light if pointed at a nearby star or large celestial object positioned to reflect that star's light. To provide a useful amount of starlight, the ship must be no further away from the star than its habitable zone and not in the shadow of a celestial body.

Lighting systems are simple and robust enough that, if there is power on the ship and the controls are not sabotaged, any room aboard may have light. Archaeologists have found that simple lights are among the first electrical devices most cultures harness with electricity before interstellar contact. There have been countless approaches to obtain more light from less power, and there are a variety of options for replaceable units that convert electricity to light such as light-emitting diodes, heated filaments, bioluminescence, plasma fluorescence and microfusion.

Modern ships favour 'synthstarlight', indirect lighting that replicates the spectrum of visible light as perceived on a typical planetary surface. The dominant standard in the Third Imperium is a cool, white light based on the light of Zan Ki Ond, the star of Capital, diffused through a blue sky, with non-visible components diminished or eliminated – particularly ultraviolet. This is close enough to the light of Sol as seen from the surface of Terra that some Solomani claim that this is the actual standard. Local environmental controls typically allow a range of hues, replicating the same pseudo-starlight at different times of day. Generally, the warmer colours of sunrise or sunset are preferred for situations where a more relaxing environment is called for, such as staterooms or crew commons, whereas cooler colours are for spaces where more focused work is performed, such as workshops or a ship's bridge. More advanced lighting systems may replicate light from different stars as viewed from atypical planetary surfaces, often as part of the weeklong acclimatisation process most ships undergo.

Biospheres use a 'grow light' or come standard with a filter that provides plants with a softer light that has all components needed for photosynthesis. These provide light for both shade and sun loving variations of plants at the same time, without over or under stimulating sensitive plants used to lower or higher lighting conditions.

A resilient trend is to design lighting to make it difficult to tell where the light is coming from. This allows the light to be brighter than normal human tolerance levels to light up more of the room but diffusely reflected by the walls, so the crew does not look directly at the light source.

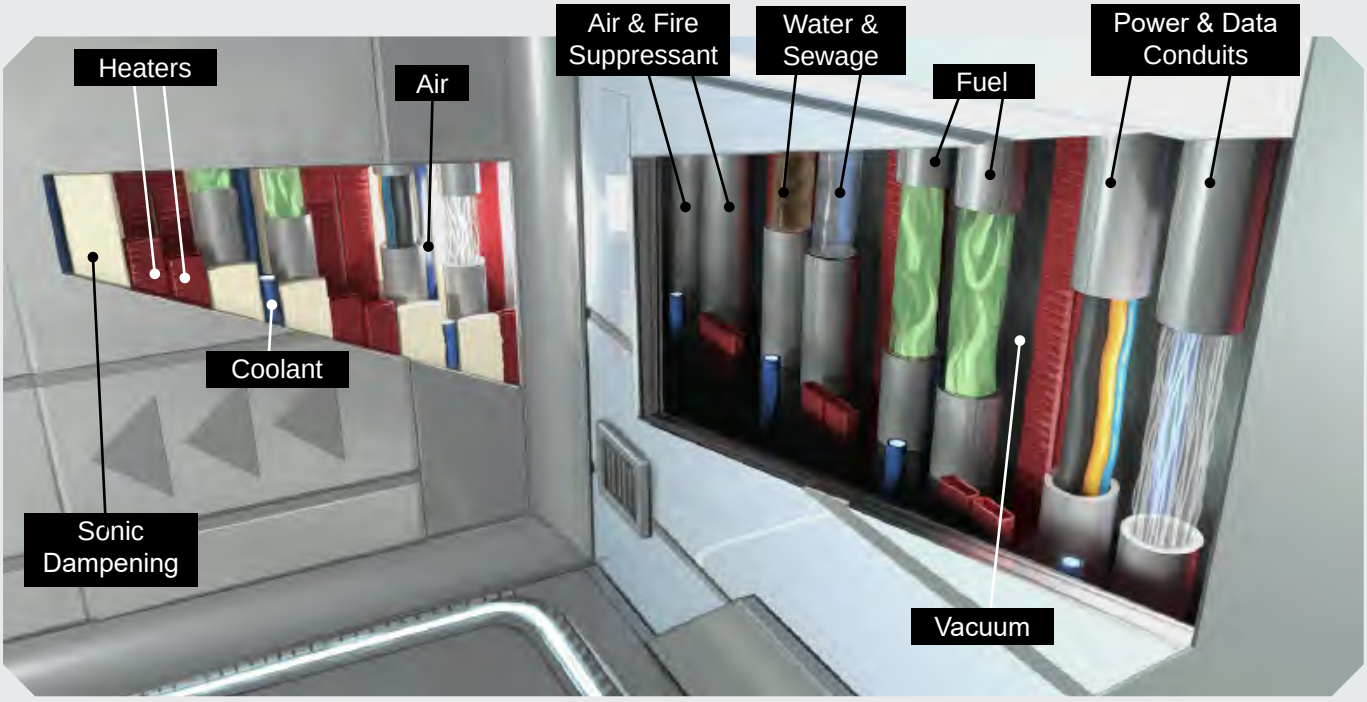
If the power goes out and no external light gets in, the inside of a starship is said to be the darkest place in the galaxy. While that may be an overstatement, it highlights the need for backup emergency lights. These lights should be regularly tested. Although off most of the time, they must keep the ship lit long enough for the duration of an emergency. Typically dimmer than normal lighting to conserve power, they often incorporate dedicated rechargeable batteries. While full white light is better during an emergency, some lower-budget ships tint emergency lights red on the excuse that this reminds everyone there is an emergency. Non-human ships use other colours that the crew can all see well, such as yellow on Vargr ships.

TEMPERATURE CONTROL

Space is an insulator. Aside from blackbody radiation, a ship in vacuum will not lose heat the way a hot object in an atmosphere or underwater might. However, a ship in orbit around or at the same orbital distance as a typical habitable world will absorb more heat from the local star than it would if parked on the surface of that world, under the protection of its atmosphere. Ship systems will often malfunction outside of a broad range of temperatures but the limiting factor is more often the crew themselves, who have a far more limited working temperature range. Given this reality, most systems are built to function optimally within the crew-limited range.

Heating is rarely a problem so long as the power is on. Many ship systems naturally generate heat as a byproduct of operation. This includes the fusion power plant, which is all about making materials extremely hot, although the amount is small enough that this is often not the primary generator. Supplementing this are electric heating units distributed throughout the crew-accessible portions of the ship. Central heating is technically more efficient but sophonts typically demand localised thermal management. This is a small enough percentage of the total power budget that crew comfort wins out in essentially all cases; even when a ship was designed with central heating, this is typically retrofitted within its first decade. On large ships, sometimes the first warning sign that someone venturing through accessways receives that they have left the portion of the ship designed for crew comfort is that it gets substantially hot or cold.

Cooling is more of an issue. Modern ships route 'waste' helium from the power plant into tubes running throughout the ship at very low pressure, relative to the fusion plant's interior, to lower the temperature, absorbing heat then venting it. Ships without fusion power plants will often store and use some other coolant, treating it as a form of fuel; a common choice



is the same liquid hydrogen that powers jump drives and fusion power plants, given how widely available it is. This flow is adjustable on a per-room basis to provide more or less cooling for individual tastes. Technically this is per-wall, so rooms next to another that is being super-cooled will experience chill from the adjoining wall. Superior life support, such as for luxury staterooms, may employ miniature double-hull style arrangements, imposing a vacuum between rooms to eliminate this effect – which can also help with sonic isolation. Lesser life support systems have solid walls except for any pipes, or employs a double wall without maintaining a vacuum.

At lower TLs, particularly before the advent of practical fusion power, this heat is often vented using large radiator vanes extending from the hull, maximising the surface area available to radiate heat. Typically fragile and prone to degradation, they are nonetheless required to prevent the ship's interior from becoming unliveable. Later advancements to materials science, thermal control and power generation make these protrusions unnecessary, although ships that run hot still require the extra surface area.

The air temperature aboard a ship is less of a comfort concern than the crew's temperature, which clothing can affect; thick multilayer uniforms aboard a warm ship can overheat the crew, while thin uniforms on a ship running cold to reduce its infrared signature can increase the likelihood of sickness. A ship may choose to run cold in certain circumstances such as venting heightened amounts of helium on the side opposite the enemy it is trying to hide from. A one-uniform-fits-all policy may be detrimental to the crew due to individual temperature preferences. This is one reason why most non-military captains prefer to allow their crew to dress as they like, within basic standards of decency. Others employ uniforms that have layers and functionality to customise to the individual's specifications.

The Imperial Navy publishes uniform standards for dressing humans and other sophonts into easy-to-use guides, freely available to all, distilling thousands of years of experience from before the Third Imperium. This has the side effect that uniforms used by civilian crews within the Third Imperium are often reminiscent of naval uniforms. The publicly available guides have subtle alterations from the standards the Navy uses to avoid accidental replication so civilian uniforms remain only 'reminiscent of' and are not confused for naval uniforms.

RADIATION PROTECTION

Stars are radioactive. Any naturally evolved sophont grew up in a radioactive environment. Sophonts with a body that naturally uses trace amounts of potassium, such as any human, are radioactive. These are tiny amounts relative to what it takes to damage most sophonts but measurable even at industrial pre-spaceflight Tech Levels.

Planetary atmospheres and magnetospheres provide substantial protection that is not available on spacecraft and must be compensated for. As noted in Basic Radiation Protection on page 9, low TL spacecraft

RADIATION

For all its hazards, radiation is one danger that jumpspace is completely safe from. Jumpspace emits zero radiation, so far as the Third Imperium's most sensitive detectors have been able to measure.

By radiation, ship crews mean particle radiation, such as alpha or beta. Electromagnetic radiation is light, lasers and so on. Gravitational radiation is gravity or 'spacetime curvature'. Acoustic radiation is sound. These other phenomena have propagation properties similar to particle radiation, which is why physics labels them as other kinds of radiation but ship crews do not.

accomplish this using mass, while magnetic fields form miniature magnetospheres on higher TL spacecraft. Most modern spacecraft store anti-radiation pills for crew and passengers in the event the spacecraft is caught unprotected in a severe solar flare or other major radiation source. Long-term care, capable of being provided by any medical bay aboard a modern spacecraft, can eventually reduce a sophont's lifetime accumulated radiation dose to essentially zero, although other measures must be taken to reverse damage.

The practical effect of this is that radiation can be ignored except in extreme circumstances, such as being fired upon by weapons specifically designed to inflict high doses of radiation or being outside a ship when a solar flare strikes.

WATER RECIRCULATION

Water is rarely consumed utterly by any of its many uses aboard ship, whether imbibed, employed in washing and general hygiene, maintaining a comfortable humidity, or putting out fires. Instead, it is transformed into another state that can be reclaimed and treated once more to become pure water. Thus, it is more correct to say that a ship has a certain amount of water than that it uses water at a rate optimally balanced by the reclamation rate. While there is inevitably inefficiency and loss over time, new water can be made from hydrogen and oxygen, two things any modern spacecraft has in significant quantities. This could in theory eliminate water storage needs but it is often more convenient to store spare oxygen as water, break off the oxygen as needed and recycle water using techniques developed for planetside municipal water systems.

A basic water treatment unit relies primarily on filtration, removing anything but water molecules and similarly sized particles, using micromanipulators as part of the filter screens to slide off accumulated junk to keep the filters clear. This combines with magnetic traps to pull out any particles with an electric charge, followed by evaporation and condensation to remove particles with significantly different thermal properties than water. Gravitic manipulation is employed during the condensation step to pull out anything with significantly different density, as well as to encourage the water to condense. One notable difference from typical planetside treatment is that the filtration step is relied upon to remove all biological material in the water, eliminating the need for any further anti-biological measures. The other steps are more to remove dirt and dissolved salts, which means multiple redundant layers of filtration, triple at a minimum, along with active monitoring to alert if any of the layers malfunction. Even

a single filtration layer will suffice temporarily but should not be relied upon long term. Another difference is that chemical disinfectants and coagulators are rarely used since they become another form of consumable and may have unfortunate interactions with sophonts the system's designers are not familiar with, not just non-humans but humans of different ancestries.

Pure water is distributed throughout the ship. Where additives are desired for specific uses, such as additional minerals and vitamins, they are added at the outlets for those uses rather than to the general supply. As with temperature, humidity levels in a stateroom are adjustable from controls in the stateroom. Luxury staterooms and special environment areas have their own mostly dedicated water supply and filtration, although these always have backup links to the ship's main water supply, usually sealed but accessible in case of malfunction or leaks. Water imported to or exported from a dedicated supply is treated before being introduced to the main supply.

WASTE PROCESSING

Garbage, whether disposed of via receptacles in most rooms of any ship or debris filtered out of the air or water supply, has two main forms of treatment.

Humans and similar size sophonts produce around a sixth to a third of a cubic metre of refuse per day, combining solid and liquid. Some staterooms allocate half a displacement ton to waste storage, more than sufficient to store waste from two sophonts for a port-to-port trip, including travel time to and from the jump limit as well as a maximum eight days in jump. Ships thus equipped are designed to offload refuse while in port, although if necessary they can dump it in space. As noted in Jumpspace Travel on page 87, dumping garbage during jump is widely considered a bad idea, although a small percentage of ships do it anyway.

Most ships have a treatment unit instead. Waste is routed to one of two central bins for redundancy and to allow one to self-clean while the other remains in use. Ships large enough to fully employ two bins will have more than two. A bin heats the rubbish to bleed off volatiles and reclaim water, which usually account for a majority of the volume, then eject the remainder, either in jump or at port. On a small ship this rarely accounts for more than a quarter of a displacement ton for the entire ship. Even on the volume and price budgets of large ships, this system is typically accounted for under staterooms, commons and bridge. Advanced waste treatment facilities, more often found on ships with biospheres or workshops capable of using ore-grade minerals, may sort the rubbish after heating, using systems akin to asteroid mining ore equipment to recover ore-grade minerals but smaller and processing at slower rates. These minerals are thoroughly sterilised, using further heat and ultraviolet light, before being routed to systems that will use them.

Spacecraft that never visit jumpspace will dump waste at port if they can store it until then, while those that ride aboard starships will hook up to and use the starship's waste disposal system.

The amount of waste produced can be reduced through optimal diet but only so much, especially for passenger-carrying ships where the initial load and the prior day, up to three days in extreme cases, depends on what the passengers had before boarding. This diet must be balanced for the individual, not just the species, as there is no one optimal species-wide diet. It requires access to optimal foods, generally requiring at minimum a monthly resupply at a high population or agricultural world if the ship is not equipped to make its own food.

On ships that have them, biospheres often double as an elaborate waste treatment unit.

FIRE SUPPRESSION

A common nightmare to deal with is fire aboard a vehicle, since even the earliest wooden boats. Water may work against a wood fire but it just splashes around the oil in an oil fire and can likewise make an electrical fire worse. These problems are made more severe aboard a spacecraft by radiative heat. Inside a planetary atmosphere, with no walls to contain it, heat from fires radiates away. In a room, particularly a well-insulated one as on most ships, heat is contained and builds up, igniting more things that add yet more heat. This can cause built-up heat to spill out through doors and bulkheads, which can ignite objects in other rooms, leading to the entire ship becoming a burned-out hulk. Interior fires are not to be trifled with.

To suppress a fire, at least one of the three things that feed it must be cut off: fuel, heat and oxygen. A competent naval architect will limit flammable materials as much as possible and implement safeguards for materials storage and handling. When this fails, or when crews bring aboard flammable materials regardless, suppression efforts fall to the other two. Heat is complicated, as cooling systems aboard spacecraft are optimised to dissipate heat output from normal operations, not from an active fire. Dispersing heat throughout the spacecraft can lower a fire's intensity but too much heat can cause ignition elsewhere aboard ship. This means the preferred method of disposing of fires on a ship is to remove oxygen.

This is one of the few times in which being aboard a spacecraft can make things simpler. Fires behave differently in zero gravity. In the absence of forced-air ventilation, fires use convection to obtain additional oxygen to burn. Convection requires a thermal differential where more-dense cool air sinks and less-dense hot air rises within a gravity field, causing fresh oxygen to feed into the flame. Turning off gravity disrupts this cycle, reducing the amount of combustion. This slows the spread significantly, buying time to start putting the fire out.

However, venting rooms on fire to the exterior is rarely a viable option. Safety interlocks on airlocks prevent both doors from being open at the same time; while these can be overridden, that takes time rarely available in an emergency. This would only be useful for a fire that happens to be near an airlock or where there is a chain of ventable rooms from fire to airlock. Non-airlock-rated doors alongside this chain may be damaged or blown open. Venting into jumpspace is widely considered even worse as jump fields are filled with thin hydrogen, with which heated oxygen might react.

There exists a solution which attacks both heat and oxygen – frozen carbon dioxide powder, known as ‘dry ice’. It works well enough to quickly extinguish most fires, after cutting off power if the fire may be electrical. Dry ice powder, chilled from carbon dioxide obtained from air treatment units, is stored near liquid hydrogen fuel and piped to miniature turret-like projector systems throughout the ship, which are often co-located with internal security cameras. The volume contained in pipes throughout the ship exceeds that of any separate dry ice tankage to assist with on-the-spot availability. Severe damage can disrupt this delivery system, usually making the projectors inoperable, leaving nothing to route the dry ice to.

ELECTRICAL FIRES

If the fire may be electrical, turn off the power first. Not only does this shut off energy that may be feeding the fire but sufficiently high voltages can arc up a stream of carbon dioxide. If electricity is flowing into where the fire is, turning it off first may save your life.

The projectors can be set to fire automatically on any heat source above a certain threshold or be manually controlled with security interlocks from a nearby control panel, the bridge, or engineering. When judging the quantity of dry ice to dispense, the projectors first try to chill the fire out of existence, then displace enough oxygen to cut off the fire that way, then consider that dry ice expands when heated into gaseous carbon dioxide and direct contact is dangerous to most sophonts. Some projectors are hooked up to the ship’s water system as well, with dedicated fire recognition software taking input from security cameras to determine whether water or dry ice will work better.

Most projectors will not attempt to hit a moving target or anything they conclude may be a living being if under automatic control. A manually controlled projector will target anything its controller aims at, although is rarely of any use in repelling boarders. Ships with an infestation of vermin – when neither evacuating air from the affected area nor fumigation is convenient – sometimes set projectors to fire at tiny moving heat sources as they are powerful enough to kill such creatures, one section at a time if faced with swarms. Any ship with pets aboard must be careful to set the maximum target size well below the smallest pet's size. Some breeds of ship's cats instinctively flush vermin into open spaces, which are often synonymous with projectors' fields of fire, rather than directly engage dangerous pests. They meow for attention if this does not swiftly result in their prey's demise.

As a backup, most ships carry detachable, manually operated fire extinguishers that plug into and are recharged from this same dry ice delivery system. Some ships only have these in the more sensitive, easy to access, centralised or emergency-prone areas. On many small ships, the cargo hold fits all the criteria. The extinguishers are kept full at all times, to remain operational if damage knocks out the projectors or delivery system. When present, their cradles are typically on the wall below the projectors, so the delivery system only needs to reach a bit further to service both outputs. The locks on these cradles use the same security system as the doors – see Physical Security, starting on page 60 – usually set so any crew, although only crew, can take them. There are also often outlets in workshops, medical bays and galleys, as dry ice blasting is useful in certain cleaning, sterilisation and food preparation tasks.

Many ships, out of concern for security or in an attempt at frugality, do without automated fire suppression and only carry fire extinguishers or replace them with ceiling-mounted sprinklers that are unable to target specific areas. In some cases they do without a central dry ice manufacturing and delivery system, relying instead on manual inspection and recharge of fire extinguishers that inevitably does not occur, too often leaving extinguishers useless. The authors of this book do not recommend this practice but acknowledge that it happens.

The less said about ships that do not even carry fire extinguishers, the better. The crew of such a ship should remedy this at the next call to a port with suitable extinguishers available to increase their odds of surviving further voyages.

Containers of potentially hazardous freight should come with attached instructions for common emergency situations; including these is standard, as it helps the ship protect the freight. There are exotic materials that create corrosive gas when burning, do not extinguish in the absence of air, or that standard shipboard fire suppression cannot put out. Speculative cargo should be inspected upon purchase or loading as standard procedure. Among other uses, this can identify if it is a hazardous material – whether or not the ship's purser thought that was what was being purchased – for which there are likely publicly available handling instructions. Cargo that seems especially dangerous might best be stored in a sealed cargo hold kept in vacuum for the duration of the trip. If cargo looks to be so dangerous as to not be worth shipping, especially if it is not exactly as promised in the shipping contract, standard responses are refusing the contract or trying to negotiate a bonus.

EMERGENCY RESCUE EQUIPMENT

While not necessary for everyday life, few ships travel without emergency vacc suits and rescue balls, typically stored in or near the airlocks. Emergency vacc suits are, broadly speaking, vacc suits that have sacrificed durability and protection against threats other than vacuum in exchange for adaptability to different body plans and ease of use. Accessed through an opening in their back, the user steps into the suit which then seals behind them. Typically, they supply four person-hours of air. Rescue balls are far simpler, taking the form of a ring with two handles attached. When activated, a two-metre diameter bubble automatically inflates away from the user, leaving an opening in the ring for user access. Once inside, the user may close the iris valve, sealing the internal environment. They are designed for single occupancy but two people can use one if pressed. This may be ill-advised, as rescue bubbles only provide two person-hours of air.

Of the two, emergency vacc suits see less use as those who routinely head out into vacuum tend to have their own vacc suits and emergency vacc suits are not easily used by sophonts that do not conform to the human body plans. Emergency vacc suits are one of those systems that are frequently put in place then ignored for years, save for mandatory inspections to maintain registration. These are mandatory precisely because starport authorities know these are often the only checks those vacc suits receive until needed, at which point there will be no time for inspections.

While it is second nature to many crew after years of practice, putting on and properly sealing a vacc suit is a skill that not everybody needs or will learn; thus the

need for rescue balls, simple self-sealing spheres that automatically inflate and can bounce out an airlock. Someone wanting to leave a ship in a hurry can simply take one off the wall, put it around them, push the button and be protected from vacuum, hopefully for long enough to be rescued.

Both sets of rescue equipment come with transponders that automatically activate when exposed to vacuum. Once away from a ship, there is nothing to do but wait for rescue. They are rarely made to last more than a few hours, so only provide air, not water or food. As such, they work for accidents in busy starlanes. A heavily damaged ship coming out of jumpspace 100 planetary diameters from the destination should attempt to steer on course and stay intact for as long as possible before abandoning ship. However, if the ship is disabled but not about to explode, it is often safer to shelter inside the wreck.

Most ships store emergency gear to keep the passengers and crew alive long enough for rescue should the ship become inoperable far from civilisation, such as from losing power in a gravity well and crashing. These scenarios presume the ship will be mostly intact, just unflyable and powered down, so with no comms or life support. A common choice for small ships is the vehicle emergency kit that is designed to support six people stranded for two weeks, assuming access to breathable air and fresh water. It consists of six survival kits and a vehicle portion.

Each survival kit is a small backpack weighing about three kilograms, containing food and water purification for four days, a knife, canteen, firestarters, flashlight, waterproof poncho that doubles as a blanket, compass with a mirror, sleeping gear and a small computer loaded with general purpose survival information. These are commonly stored near each crewmember's duty station. Crew are encouraged to customise their kits with more items and any personal medications upon signing aboard, then seal it until needed. Inspecting the contents and replacing expired medications or equipment should be done annually.

The vehicle portion is closer to 60 kilograms and contains an emergency beacon, 60 person-days of food and water, medkit, three two-person tents, hatchet, heavy-duty multitool, six-person inflatable raft, disassembled survival rifle with 100 rounds and air filtration gear that can be assembled into six filter masks. There is a bit of spare room, into which prepared or cautious crews add a survival still, rope, binoculars and a second emergency beacon; crews that trim emergency preparations to save Credits often leave these out. This comes in a heavy case that can be unfolded into a sled, although it is most often left aboard ship, thus its name. The vehicle portion is usually placed in a small locker attached to or next to the pilot's or captain's seat.

CALL FOR RESCUE

A starship with damaged or inoperable communications has many options to signal for rescue. The most important thing to remember is that potential rescue ships have fully operational communication systems, so an emergency signal does not have to be powerful to be heard. In descending order of practicality, common options are:

1. Any active sensor. Turn it on, point it at the mainworld and keep flicking it on and off. Sending SOS or Signal GK works well but even random flickers can be interpreted as a sign of distress.
2. Weaponry. Yes, really. A defocused beam laser makes a fine way of getting attention at extreme range. Take care not to shoot rescuers with a full-power beam when they come within range.
3. Any portable comm system. Tape it up to a viewport or throw it out of an airlock. Vacc suits and rescue balls all have emergency transceivers, many crewmembers will have personal communicators and starship emergency kits are supposed to have a set of GK pucks, palm-sized orange disks designed for this exact purpose.
4. A spark-gap radio. If the ship has no communications devices or anything onboard that can generate signal, create a simple spark-gap signaller with a power source, vacc tape, a piece of wire and non-conductive gloves. Tape one end of the wire to the positive terminal. Touch the other end to the negative terminal while wearing gloves. This will generate a brief burst of unmodulated radio waves. Repeat as needed, ideally in front of a viewport so the transmission escapes into space.

FOOD STORAGE AND PREPARATION

Food storage is vital to support life on a starship, almost as much as air. While most staterooms have miniature kitchens that have some storage space for food, the bulk of storage will be in the cargo hold. The average sophont eats around two kilograms of food per day. Most food with packaging weighs approximately 1,000kg/m^3. One displacement ton, which is 13.5 cubic metres of food, is thus about 13,500 kilograms and will last the average sophont 6,750 days. Ships typically store food for their maximum expected occupancy for as long as they have reactor fuel or more, often four weeks. A four-person crew thus needs 112 person-days of food, less than 0.02 tons. Given the trivial storage requirement, buying and storing long-shelf-life supplies as backups is common.

Thus, the main concerns when buying food at starports are quality, convenience and price. For a crew without a competent steward or cook, pre-packaged meals are more important than the finest of raw ingredients. A purser should always make sure the food is good quality and not expired, even if the price is low. Cheap, expired meals risk the added cost of medical treatment before the crew can go back to work and low-quality meals risk crew morale, which is critical for ship operations.

While subsisting on pre-packaged foods is an option, many crews prefer to prepare their own meals from raw ingredients. Whether one descends from the Vilani shugilii or not, personally preparing food for crew bonding is one of those rich traditions going back well before spaceflight.

However, the Vilani developed their shugilii for good reason; on most worlds, even Vland, native life is simply incompatible with the digestive systems of sophonts whose ancestors hail from other worlds. Special preparation techniques are needed to make ingredients edible, mostly ways of breaking down or denaturing proteins, identifying and reliably removing toxins, and making the taste palatable. On modern ships, these tricks form the essence of the galley.

Having or not having a galley places a sharp distinction on the food portion of life support. Without a proper galley, a ship is limited to food obtained from civilisation of some sort, usually a starport, and is vulnerable to accidents destroying or spoiling the food stores. With a proper galley, a ship's crew can forage for ingredients on most life-bearing worlds. Paired with wilderness refuelling, this extends the length of time a ship can be away from port, although it must still carry spare parts for maintenance.

For some, the most visible reminder that space is ever at a premium aboard a ship is the galley. Where a planetside kitchen might be wide and open, a galley will stack ovens and cupboards and rarely have much unused counter space. Even small galleys aboard ships have an industrial, mass production feel. Having a single washer/dryer unit for plates and cups as well as laundry can strike some as unhygienic, despite all the studies showing the results to be as clean as separate units.

Some ships do not have a kitchen, instead carrying prepackaged meals and rarely stocking more than four weeks of food at a time. These ships tend to have longer stays in port, relying on services there to do tasks such as laundry. This does afford more time to do whatever the ship's crew came to do, although it requires a way to pay the mortgage that does not rely on fast turnaround in port. Mercenary ships that can count on non-hostile reception at most ports sometimes work this way.

THE SAFARI SHIP

The *Animal* safari ship is specialised for storage of raw food materials, dealing with aspects that most sophonts never spend much thought on. Even if the owners are more concerned with trophies or live animals than procurement of meat and provisions, there are built-in options to accommodate the latter.

The *Animal* is not the only ship that performs this function. The generic term is 'safari ship' and is common enough that it gets its own subtype code. The safari ship is presented in this book as an example of specialising a ship class for an uncommon mission. Any average educated sophont in the Third Imperium might guess that a scout like the *Suleiman* would have probe drones and good sensors or that a trader like the *Empress Marava* would have extra cargo space but there are many less obvious missions ship classes are designed for.

The *Animal* comes equipped with two separate multi-environment holding tanks that shine for their versatility. They can turn into simple freezers for storage of bulk amounts of perishable food but act as holding pens for live animals. Meat gatherers keep the tanks at or near freezing, so stored meat can make long journeys where needed. Taxidermists and vets keep the tanks at a more normal temperature, mostly for their own comfort as they work, although vets must accommodate the animals' needs first.

Each tank floor has a built-in extendable metal table that can raise an animal or its carcass to a desired height. This allows the cutting of meat for storage, tanning of hides for taxidermy and examining tranquillised animals by a vet. The launch hangar has a similar table, for animals that cannot fit through the ship's internal iris valves. When not in use, these tables retract flush with the deck. The ceilings have a wide variety of eye plates, tie rings and hooks to aid hunters if they wish to string up meat for cleaning, cutting or storage, handy for restraining live animals, hanging other equipment or securing storage containers from the ceiling.

In addition, many crews install tool cabinets just outside the tanks, although each crew customises the tool set for their own needs. A meat gathering group may have large bone saws, knife racks, and meat grinders. A taxidermist may have bins of fake teeth or eyeballs along with tanning equipment. A vet working on live animals may have tranquillisers and medicines.

SANITATION

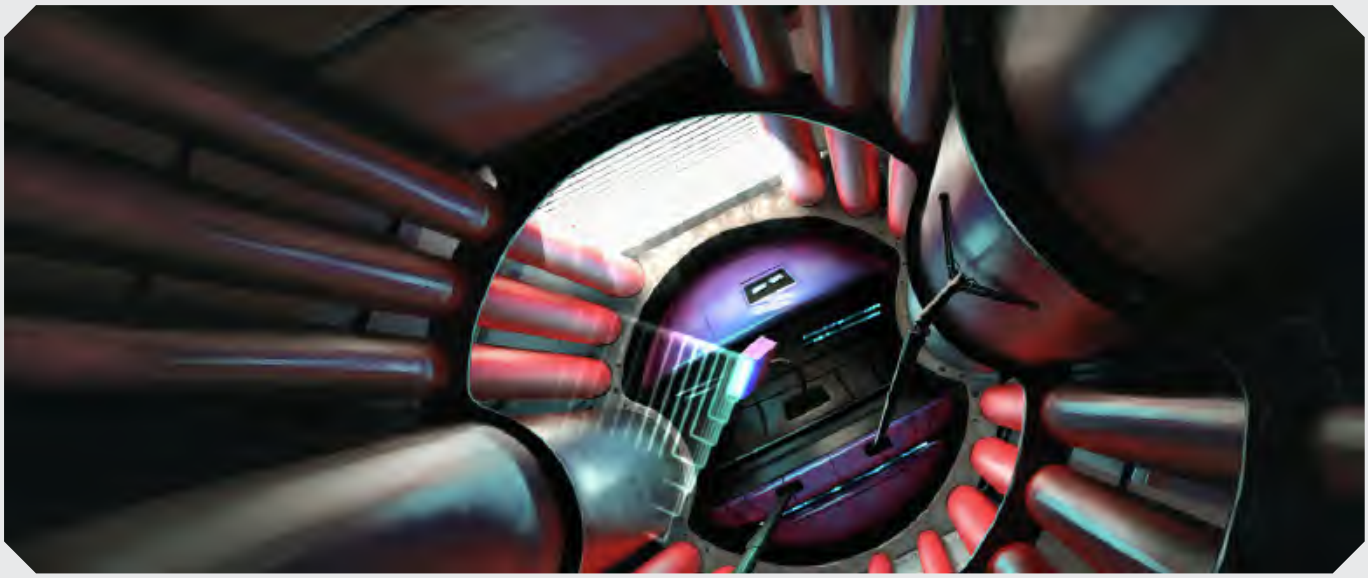
Keeping a ship clean and liveable is one of those tasks that many sophonts prefer not to deal with, automating it as much as possible. Common criteria for what jobs are best to automate, such as 'difficult, dirty or dangerous' jobs, often bring to mind sanitation as the primary example of 'dirty'. The fact that one cannot readily 'air out' an occupied structure in space adds some wrinkles to how this is done on a ship.

PLUMBING

There are a number of pipes in any ship carrying fresh water, sewage, liquid hydrogen fuel, gases and other substances. Keeping these unblocked and not leaking is important. On any but the most titanic of ships, piping is never large enough for most adult sophonts to crawl inside, so remote options to fix them are vital.

Pipes are built to not chemically interact with whatever is inside them, thus low-TL steel that can rust is not an option for water or sewage pipes. Pressure sensors are distributed along all piping; an unexpected drop or increase in pressure can be a sign of a blockage or leak in the line. For example, when trying to activate a fire suppression turret in an emergency with limited time to conduct diagnostics, it can be useful to immediately know whether the turret is not firing because the pressure to its supply is off or if there is another reason.

Most ships do not embed piping solidly within the hull but instead leave empty space for a 'pipe runner', a spider-like drone that can crawl along the outside of a pipe looking for breaks or blockages. This tool can be equipped with one of several tools to safely repair a break. Equipped with ultrasonic sensors, a pipe runner can detect blockages without opening the pipe and use vibrations to break these up. Higher TL versions instead use a densitometer and micropressors, which are essentially tiny gravitic fingers. Should the blockage stick tightly enough that the pipe runner cannot dislodge it or if the leak is too large, the recommended procedure is to temporarily shut off the flow then use a welding tool to cut out and replace the faulty section. Blockage-clearing implements are also used to clean



the outside of pipes, where more direct cleaning methods cannot reach. Some ships that employ cleaning drone swarms rig these to carry out plumbing maintenance rather than have separate pipe runners. The plumbing tools can be larger than the individual drones, so multiple drones team up to manoeuvre and operate them. These swarms are programmed to conduct pipe inspection and maintenance on their own, especially when the ship's computer alerts them to a failure, taking one more set of tasks off the crew's hands. These ships still require pipe runner accessways but by not having a separate type of drone, there is one less thing that needs maintenance.

While leaving empty space for a pipe runner can seem inefficient, this is a time-tested practice in the maintenance and emergency repair of spacecraft over thousands of years, particularly when replacing broken sections. The 'inefficiency' is most often minimised by having several pipes surround a common pipe runner track. The most often proposed alternative requires pipe runners to travel inside pipes but this may be impossible. For example, liquid hydrogen is notoriously difficult to operate within and requires ways to bypass shut off sections of plumbing when investigating leaks.

LAUNDRY AND DISHWASHING

There are three general approaches to washing clothes and dishes. Some ships that frequently see port simply store anything that needs washing and clean it in port. Ships with luxury or multi-environment life support areas may splurge on separate dedicated machines for each area of the ship. A compromise is to have one or more clothing and dish washers in the commons so the crew can access them.

The main problem with the first method is that storing used material requires space separate from clean material. This is rarely formally allocated but generally seen as inefficient if it goes beyond three weeks' worth. Also, not every port has a laundry service, so it is recommended that ships that adopt this approach have a minimum of 21 days of clothes and dishes for all crew and passengers who will stay for two jumps or more, and 10 days for any passengers who will not stay for more than one jump. Naturally, most captains prefer to leave it up to each crew member to make sure they have this much clothing but anyone that falls short becomes a problem for everyone on board. Thus, this method is not recommended for ships that typically do multiple jumps per mission or do not want to spend additional time docked or lack space for extra storage.

Some ships prioritise cleanliness and despite space aboard a ship being at a premium, luxury and multi-environment life support may need their own washing facilities to avoid contamination. It is rare for even a luxury stateroom to have its own dedicated washing machine unless it is the only one aboard. More common is for there to be one machine for all luxury staterooms and another, shared with the dishes, for the others.

Multi-environment spaces more often have their own machine, although it is rarely used and often sealed away. An *Animal* that only uses their multi-environment spaces for freezers or pens for oxygen-breathing or aquatic animals may not use a washing machine, whereas an *Animal* that sets one up as a properly humid stateroom for a Bwap may use one frequently. Some see this as excessive while others see it as necessary.

The solution most small ship crews are familiar with is the common washing/drying unit. Some ships have one for dishes and one for clothing, while others have dismountable racks, put in to wash dishes and removed to wash clothes. As with showers, ultrasonics, steam and hot water are the three most common methods of cleaning. A ship will often use the same method for washing machines as it will for showers if these are not individually selectable. Most modern washing/drying units will allow the crew to select from all three options, although checking with the steward and rest of the crew is advisable due to any conservation methods or cleaning schedules.

CLEANING

A ship in space can be considered a mobile house, with all the usual cleaning needs. Tools and supplies for this are typically stored either in the ship's locker or, where there is no ship's locker, the cargo hold. Brooms, towels and vacuum cleaners can suffice for regular cleaning maintenance and are the favoured method on many ships, particularly those that only engage in annual maintenance. These leave thorough cleansing, especially of usually-inaccessible areas, to be part of an annual task, trusting that not too much bacteria, mould, dirt and sediment will build up. Cleaning takes time to perform and is usually assigned to otherwise-idle crew, particularly while in jump. When a ship does not perform annual maintenance, it may become a task for the entire crew, requiring advanced tools to clean all the hard-to-reach areas.

Other ships automate the task, whether out of efficiency on large ships or because a small crew might simply have no members who can tolerate doing it. While janitor robots are familiar from fiction, a more common solution is swarms of tiny robots like those employed in certain washing machines. Most of these robots have an array of tiny brushes and manipulators with which they remove particles of dirt and dust, buff out small dents and scratches on hard surfaces and mend tears in fabric. A few specialised models spray customised detergent to treat and remove stains or bring empty dispensers to suck up liquids for disposal. All robots have visual and thermal sensors, with dispenser models having basic chemical 'sniffers'. These robots venture forth from central hives, which supply power, tools and detergents, as well as basic maintenance. On large ships these hives are distributed throughout the ship. On small ships, the single hive is usually in engineering or, if there is one such as on *Suleimans* that use this method, the workshop for ease of fabricating replacement parts or bots.

Cleaning is done on a preset schedule but anyone can report a dirty area to the ship's computer, which will alert an available swarm. The swarms are programmed to avoid areas where crew are active, which can lead to always-crewed areas getting less cleaning; some captains look forward to jump as an excuse to leave the bridge uncrewed briefly and let it be cleaned. While swarms are programmed to avoid any large moving object such as a sophont, a pet or even a larger robot, this can be overridden. Having a swarm crawl all over oneself takes some getting used to but can give efficient cleaning while remaining dressed. Sweat is just one liquid they can dispose of, which can be particularly useful for not having to fully remove a vacc suit during a long work period. While taking a break in an airlock

MEDICAL CAUTION

Even if you are not the ship's medic, it is a good idea for every member of the crew to know the location and contents of the ship's emergency medical supplies. If your ship does not have adequate medical supplies, be sure to let the captain know at once so that plans can be made to acquire them at the next opportunity.

It helps to be familiar with the medical symptoms of failing ship systems, such as a migraine potentially signalling poor oxygen levels. In most cases, these serve as flags to check with the ship's computer to see if that failure might be happening. This is no replacement for sound medical advice, as it is quite common for the untrained to misdiagnose themselves. However, when ship system failures happen, detecting them early means more time to prevent them from killing the crew.

If you see someone helpless on the floor or floating in front of you, call it into the bridge and determine the cause before attempting to help. Grav shears from malfunctioning grav plates, high pressure jets of gas from a leaking pipe and other causes invisible to the unassisted eye may still be present. There are three main reasons to stop first aid; when someone more qualified can take over, when you have run out of aid you can provide, or if you are at risk of becoming a casualty. Do not walk into an unknown danger and become another victim.

to recharge the air tank, one can simply pop the helmet and let the swarm in to do its work. Some marines employ this practice while recharging battle dress so they can remain suited up in dangerous conditions.

MEDICAL NEEDS

While not all ships have a fully stocked medical bay, all ships must be able to provide basic medical attention to crew and passengers. Some try to stock only the bare minimum of a first aid kit, but this is only sufficient for those lucky enough to not run afoul of radiation sickness, oxygen deprivation or any hazards of space, let alone medical conditions unique to certain worlds. When accidents happen on a starship it is often days or weeks away from any other source of treatment. Thus, a well-stocked starship will have compact medical equipment aboard. At a minimum, enough medikits for the total count of crew and passengers, and basic, freely available medical software for any console to call up so the crew can return to work quickly.

Handheld infrared and chemical scanners loaded with diagnostic software, laser scalpels with adjustable beam sizes and self-sterilising bandages treated to speed up dermal regeneration are the most well-known components of TL10 medikits. TL12 versions include portable microtractor emitters to manipulate bones and internal organs without breaking the skin. Unfortunately, due to the wide range of manufacturers the exact tools and supplies vary, so two brands side-by-side on the same shelf, let alone from starports on different worlds, are rarely identical even if they are the same TL.

LOW BERTHS

The exact hardware of low berths varies. Some are advanced versions of cryonic booths, whilst others employ advanced versions of fast drug, giving better time dilation than the 60-fold increase of ordinary fast drug. Some use sophisticated anaesthetics that last for a week but make subjects less conscious than in sleep, placing them in a vulnerable state. All forms of low berths suspend the user's animation for the duration of the journey. Most suspend or drastically slow ageing as well and are ideal for extremely long journeys. Regardless of the means used, a passenger enters the low berth, has a temporary sensation, then ideally wakes up at the far end of the trip. In all cases, low berths are internally padded and come with diagnostic equipment to make the trip safer, as someone who will not wake up from earthquake-grade vibration is vulnerable to injury in ways that those who have never been in low berths rarely consider, particularly since their flesh can be solid and brittle in this state.

There are three types of ships that employ low berths. One type only has them as emergency backup in case of an accident, so if something happens to a crew or passenger that cannot be readily fixed on the spot, the affected person can ride in a low berth until the ship gets back to port. These ships do not use their low berths for routine commerce. Ships that do not even have a full medikit on board sometimes use this approach to appear sufficiently medically responsible to pass inspection. It works often, although for small ships it is recommended that a full medikit and minimum of two crewmembers with basic medical training, in case one of them needs treatment. In addition to superior on-the-spot response capability, a medikit takes less tonnage and power than a low berth.

The other two types of ship take on low berth passengers. The more infamous type skimps on as much as they can, including the quality of medical help. This type of ship made the 'low lottery' popular, where passengers bet on how many people will survive the passage. Any passage on which there is a significant chance of dying is one generally only undertaken in desperate circumstances. Few are that eager to see the stars, especially knowing they will likely never again see anyone or anything they leave behind. Such desperate passengers are rarely in the best of health or circumstances, further lowering their odds of survival.

Then there are the types that do it right, with autodocs to revive anyone at the first sign of system shock, trained medical staff and good software assistance. Survival rates are much higher on these ships. Expenses are too and they can only charge the same rates to stay competitive. When ships with autodocs are known to operate the desired routes, the riskier types tend to lose business, with reputable ships not only stealing existing passengers but finding more willing to brave this form of travel. This causes other dishonest middlemen to appear selling low berth tickets to reputable ships only to switch them to risky ships offering low berths on the same route for a cut of the profits. Fraud of this sort contributes significantly to the low number of reliable transports, which contributes to the entire class being labelled risky, in a vicious circle of feedback.

Some ships without proper low berths, whether or not they have emergency berths, offer to let passengers take small doses of fast drug to skip most of the trip, spending the approach to and week of jump in a few subjective hours in passive activities such as a nap, reading, listening to and/or watching media slowed down to their perceived rate of time. Given the variable time spent in jump, passengers taking this option frequently wake up with several hours left until the

ship reaches port, which is often complained about. However, there is a much-reduced risk of medical complications. This type of passage is commonly regarded as a subtype of basic passage, in particular regarding acceptable standard rates and the lack of expected steward service.

When considering travelling via low berth, it is advisable to check if the ship is equipped with autodocs, a fully trained medical staff and other lifesaving equipment needed to ensure survival. With few exceptions, passengers have the right to inspect a ship prior to booking any level of passage, either in person, through the ship's security cameras or via a travel agent. Many passengers are unaware of this. If this is not feasible, it may be wiser to save up the money for standard passenger tickets. It is strongly suggested to avoid travelling on ships with a 'low lottery' in place. Even disregarding the condition the low berths must be in to make it popular, it is tradition that, should the winner of the lottery be among the dead, the captain wins the pot, which generates incentive to reduce passengers' life expectancy further. Those who run a ship with a low berth system that takes on passengers should be transparent about the medical equipment and staff available.

COUNSELLING

The crew and passengers of a ship in space have only each other to talk to and are confined to the ship for several days. No known sophont species evolved in such circumstances and few individual sophonts grow up in them. This can be psychologically stressful, especially to those who have not yet travelled much. Providing counselling is the traditional response, whether from a ship's steward or from artificial intelligence. Derived from TL7–8 efforts to make the first AIs capable of holding conversations, commonly termed 'chatbots', AI counsellors are available at TL9 and often included for free in a ship's basic software.

Small ships, often lacking a dedicated counsellor to support the crew's psychological needs, generally rely on the many programs in any basic library to help the crew. Often, the biggest hurdle in treating psychological needs is getting those in need to use the programs despite them being free, available to all crew privately and can be done at any time. Many are not aware the programs are available or believe that they can wait until the next starport to seek face-to-face counselling. These programs pull from a diverse set of topics and psychological conditions. One TL12 example that

obtained good and consistent marketing, 'The Doctor is In', allows the patient to sit in a virtual environment such as a doctor's office or field of flowers to talk to an attentive and caring individual about the issues they are facing. While it does not replace a certified psychologist for advanced issues and many prefer a sophont counsellor to a computer, these can help with some issues arising from long journeys across the stars.

STATEROOM EQUIVALENTS

Further crew support options are detailed in the Amenities chapter. Although it is not recommended, most sophonts can survive sleeping in a cargo hold if a ship has no staterooms available. Additionally, some amenities place further stress on life support systems.

The most common measure of ship occupancy is the stateroom equivalent. While proper form is to rate a ship by the maximum number of sophonts it can support indefinitely if properly supplied, many ships instead count the number of stateroom equivalents. One ordinary stateroom counts as a stateroom but so does one cell of a brig, a couple of barracks beds and other rooms that support one or two sophonts. Maximum long-term occupancy is understood to be twice the stateroom equivalent count, with the implication that supplies are sufficient to handle this.

Stateroom equivalents in the Third Imperium are measured with respect to humans or sophonts with similar life support needs. Prospective ship owners and crew who are or represent non-humans or significantly divergent humans need to be aware of any important life support differences. Being stuck on a starship that lacks compatible food or provides insufficient oxygen recirculation can be a matter of life or death. K'Kree are a famous example of special psychological needs as most require vast open areas and react violently when brought aboard a typical spacecraft, with exceptions being enough of a political embarrassment to the steppelords that they are sometimes hunted down. Human passengers should take precautions when booking passage on starships designed for non-humans. Being stuck in a vacc suit when no one else aboard needs one is psychologically stressful and potentially hazardous, as most vacc suits are not designed to sustain an occupant during a weeklong jump without pause.

Luxurious life support, used to cater to high passengers, can result in higher life support costs. This does not reflect a higher maximum occupancy but instead a more refined grade of support (see High and Luxury Components on page 110). Replacement parts such as filters being built to a higher standard are more expensive, although they rarely require more labour to maintain.

Special environment life support systems are segregated from primary life support as much as possible to avoid cross-contamination. Some higher-end luxury life support systems are likewise segregated for the same reason. A luxury passenger might have the air in their stateroom optimised for their body and state at any given time, such as one mix for sleeping and another for work. However, this leaves them open to life support tampering. There have been events where the alarms were disabled and a noble's personal quarters were sealed off, then the oxygen concentration was slowly lowered to fatal levels while the noble slept. Some passengers insist on their own air systems all the same, prioritising luxury over safety.

Some ships offer alternatives to staterooms, such as brigs or barracks. These can be functionally viewed as special types of staterooms for most purposes, in particular life support. Brigs are staterooms with fewer amenities but more security, often including a security station overseeing groups of brigs if there are enough of them. Barracks are low-amenity high-density staterooms only suited for those who will put up with cramped conditions, such as soldiers or basic passengers. Suites are groups of staterooms, sometimes including a small common area.

Some cultures have stateroom-like areas that house no one, the most famous example being shrines on traditional Aslan Hierate ships, although ships belonging to particularly religious spacefarers often use the same approach, such as the personal temple-ship of a travelling priest. Rooms such as this are usually built as standard staterooms with the furniture replaced, so a typical shrine has its own air purification unit, albeit one that does not increase the number of sophonts the ship can support. These are specifically tuned to regulate incense fumes, mostly to make sure the scent does not spill out into the rest of the ship.

CARGO AND DOCKING SYSTEMS

Airlocks, hangars and docking bays exist to transfer items to and from a ship. In most cases, a ship would be useless without some way for sophonts and cargo to board and disembark.

DOCKING OPTIONS

Docking is the first step to transferring cargo and passengers to another ship or starport. There are three general means of travel between ships, including from a ship to a port or vice versa.

OUTSIDE

Origin and destination may not be in contact at all. They may be floating next to one another in space or parked at a downport. One exits the origin ship, crosses the intervening distance, then enters the destination ship. If the intervening space is hazardous, such as vacuum or a volume into which hostile fire is being directed, protection is advised. This includes most boarding actions, where entry into the destination ship can be difficult, particularly if the target ship does not wish to be boarded. At the other end of the spectrum is simply walking into a ship on the ground through an open cargo hatch or ramp.

Unlike the other two options, this does not allow one ship to move another ship without tractor beams or other indirect means, so they are not considered 'docked'.

DOCKING TUBE

The most common form of this is a pressurised tube connecting the two ships, large enough that items or crew can pass between them in a controlled space. When not in use, this tube can retract into the hull around the airlock, extending only when needed. Traversing between ships is much easier in this contained area, greatly lowering the risk of floating off into space and other hazards. Since almost all ships have standard airlock sizes, connecting tubes have little difficulty mating to other ships' airlocks.

This technically includes cases where one ship is attached to another like a limpet to grant armoured protection to passage between the ships. It also includes docking clamps, which often incorporate tubes and nets for hauling otherwise unattached cargo. Nets are especially useful for tenders that carry non-jump spacecraft from star-to-star and other ships that carry large, irregularly shaped cargo.

Care must be taken when engaging reaction, manoeuvre or jump drives while docked with another object, as the combined mass and volume will be propelled by the drive, lowering overall performance. Reaction and manoeuvre drives can suffer from a misaligned thrust axis, causing unwanted attitude changes. This is a more critical issue for jump drives since attempting to propel more than the drive is rated for tends to result in either no jump or misjumps. Nets intended for this contain jump emitters, extending the jump field to include the net and everything within.

INSIDE

The destination is inside the origin or vice versa. There is no intervening space to cross, just a single opening, be it an airlock's outer door, cargo hatch, hull breach or something else.

While less flexible than nets or external clamps in terms of the size of ship or cargo that can be taken, this arrangement is simple enough that it is far more common, with no effect on manoeuvre or jump drives as those are rated based on external volume rather than mass. It has the advantage of being able to take cargo up or down through an atmosphere without risk of damage, which is not possible with most external docking solutions.

AIRLOCKS

Entering a starship usually requires going through an airlock. The concept stems from low-TL locks that move floating vessels between bodies of water at different elevations, pumping water in or out while enclosed around a vessel to allow it to float in at one level, wait for the change, then float out at the other. Airlocks are much the same, except transiting between areas of different pressure and/or atmospheric composition. This is typically accomplished by pumping air into and out of the airlock's internal volume, which can lead to a notable weak point – a high-pressure air tank

behind the vents. It is under more pressure while the airlock is depressurised but can cause an explosion at any pressure if penetrated. Fortunately, the pressure containment vessel acts like armour, so even if an errant slug strikes, most small arms fire is unable to penetrate it. Deliberately using an armour-penetrating projectile to rupture this vessel and cause an explosion in an airlock on one's way out of a ship can backfire.

Although early airlocks could take almost an hour to complete a full cycle, airlocks of TL9 and above can cycle in a minute or less. This time is reduced further by there being no need to acclimate to pressure differentials. Modern vacc suits can comfortably operate at a range of internal pressures, typically matching the environment that the user has just emerged from, eliminating the risk of decompression sickness.

Airlocks are typically situated at or near the outer hull, preferably close to the ground. On many small ships they are at a minimum distance to the bridge to facilitate rapid boarding and take off. As a result, although most airlocks are a simple horizontal corridor with hatches on either end, some integrate access points above or below their main chamber. The same systems used for interdeck access can be applied, with an emphasis on resealing behind the user. For lift platforms this is trivial but stairs and ladders can both be complicated. Airlocks on a ship's bottom or lower sides may hinge the floor or a wall, forming a boarding ramp or staircase when open. Ladders are less common for this but can help reach a horizontal airlock hatch that is well above the ground.

Completely internal airlocks exist as well. These are typically used to access subcraft or cargo bays, which may become depressurised over the course of their normal operation. Adding an airlock allows the crew to always access these areas, where they would normally need to repressurise the entire bay to permit access. Certain laboratories or other areas with potentially hazardous atmospheres include airlocks for safety.

Vacc suits are stored close to airlocks for expediency's sake, typically either within the airlock or in lockers directly outside. The latter is common among exploration ships, who may wish to perform maintenance on their vacc suits while the airlock is in use or aboard ships with more than one external airlock leading to a common foyer. This setup allows more room for the crew to don their suits and prevents the airlock from becoming any larger than it needs to be. However, it will take up more tonnage and may limit access to the crew's preferred suits should the area depressurise. In either case, emergency equipment such as rescue balls and emergency vacc suits will always be found within the airlock. To prevent unauthorised access and limit environmental wear on personal vacc suits, they are kept in sealed lockers when not in use, usually assigned one per crew member and secured by keypad or biometrics to prevent fumbling with physical access tokens in the event of an emergency.

In addition to regulating pressure, airlocks can decontaminate an object before it is allowed on the ship. This is great for worlds that have known viruses, pollen and other irritants that can be harmful to the crew if brought aboard. The scanners in these areas are so precise that they can track microscopic parasites and bacteria. They routinely disinfect open wounds, as a tiny scratch could lead to a deadly infection if not treated before coming aboard. The airlock uses lasers, water and other detergents as needed to remove these and other hazardous substances before they can multiply in the confines of the ship and make the crew sick. Stewards or other crew who like to keep a clean ship find the dust and debris filtering extremely helpful, especially when paired with less hygienic crewmates or passengers.

It is a mark of one new to space travel to be surprised by the sometimes noisy and aromatic decontamination process when passing through an airlock. Lower TL scanners often have cues that indicate when an inhabitant is being scanned, either through the whirring of a camera's actuator or the light of a laser scanner. Most advanced models do away with this but some keep it intentionally. Projectors line the walls in several rows from floor to ceiling, hissing as they release the liquid or gases needed for decontamination.

This decontamination process only affects the outer vacc suit or similar protection. Entering with a vacc suit on may lead to parasites and pathogens getting aboard if they ride inside the vacc suit. Some medical professionals insist that crew take off their vacc suits or disrobe when coming back from missions with a known pathogen exposure risk; this becomes standard procedure if routinely exploring unknown environments. Cargo airlocks and docking spaces do this too but simple cargo bay doors or ramps do not usually come with decontamination equipment, so crews on ships with these must stay vigilant when visiting areas with tainted atmospheres.

SUBCRAFT DOCKS

Subcraft are more common on larger ships, many of which stay in orbit and rely on them to make trips to a world's surface. Small ships more often land directly

on worlds. Nonetheless, subcraft are of use on some small ships too, including the three examples in this book. All three ships feature an air/raft, while the *Animal* has a launch which traditionally comes with its own vehicle, an ATV.

The reasons to carry subcraft vary with the range of missions a ship is expected to carry out. Common reasons include:

- **Beyond-starport access**. Many worlds limit starships' access of their atmospheres to downports and the airspace immediately around them, or do not allow starships closer than orbit, regardless of ship size. Subcraft are usually allowed, subject to licensing and traffic control restrictions.
- **Wilderness travel**. Laws aside, a starship cannot just land anywhere. Put down in a large, sticky patch of mud and a ship may need more than lifters to take back off. Most subcraft are more capable, as they can fit into narrow areas and stir up less mess when travelling beyond a world's starport.
- **Limiting risk**. The cost of a subcraft is a small fraction of the smallest starship and they are far more widely available. It is thus far easier and cheaper to replace lost or stolen subcraft. Further, if a subcraft is damaged and a crew needs to make a hasty exit from a world, it can park aboard its ship, with repairs waiting until the ship is safely away.

These reasons have applications specific to ships' missions. For instance, wilderness travel has applications for the survey missions a *Suleiman* might conduct. For an *Animal*, the ATV can approach many animals that would flee if a starship came near. Being able to transport goods to and from potentially remote locations is sometimes required for an *Empress Marava*'s crew to receive the best deals.

Docking spaces and full hangars are not the same. Docking spaces are roughly conformal to specific subcraft with barely enough room to dock and squeeze around, either enclosing the vehicle or offering a dedicated airlock. Full hangars always enclose the vehicle and offer enough room for repairs and maintenance. Ships with only docking spaces usually maintain their subcraft while at port or landed on a world.

There are many configurations for a docking space, including extending docking clamps from inside to pull the vehicle into the ship. Many bottom-loading docking spaces use these instead of requiring the pilot to hover the craft inside the docking area until the bay doors close so the vehicle can land on the doors or rest in the clamps' grip.

Drone hangars are little more than large airlocks that the drones are stored in. When not mid-launch or recovery, crew can walk in and service or program the drones, although care should be taken before opening the outer hatch to prevent any unwanted spacings. Drones may refuel liquid hydrogen stores from the ship's fuel tank, so the hangar typically has one or two hoses for this purpose. Tools and parts to service drones are brought in as needed rather than being stored in the hangar, as this would risk losing them in a decompression event and these tools are

often useful in other applications. As with any docking space, it is possible to use drone hangars as backup airlocks in an emergency.

ESCAPE PODS

Most craft do not carry dedicated escape pods, as they tend to place crew who were safe in orbit into dangerous situations. The main exception is for military or paramilitary ships which might draw a swarm of incoming missiles, giving enough time to eject before they hit. Most other causes of imminent ship destruction either do not give enough warning to eject, present a situation such as a crash landing where staying inside the ship is more survivable, or are caused by something inside the ship that can be ejected such as an explosive or poison gas. Re-entry capsules are more useful for rapid insertion into dangerous situations, such as for an assault or rescue ship.

Subcraft can be used as escape pods on ships if present. An air/raft is among the most common subcraft; while it has an open cockpit and is underpowered by the terms of space vehicles, it is perfectly adequate for limited space manoeuvres followed by a suited or rescue-balled descent to ground. Subcraft should never be used this way unless the parent ship is a hulled wreck that has been fully looted of anything that could sustain life or is on an intercept course with a planet or other massive object. Even in the latter case, first consider whether the subcraft's drive could nudge its parent ship into a stable orbit or a course that will miss the object.

FITTING LARGE CARGO

Many cargoes come in standardised containers for ease of handling. Nearly all starship captains are familiar with the standard One Cubes, a one-metre cube with tiny spherical wheels set at the bottom and indents along the top to allow these to lie flush against one another. One of the sides swings open to provide access. These are sized to pass through standard iris valves and commonly found on all sizes of trader ships. Like all standardised cargo container types described in this section, cubes with environmental controls or other power needs have internal batteries with 24 hours of charge, designed to wirelessly recharge from common starship or starport chargers, passing charge from one container to another.

Less common is the Tonner, like a One Cube but three metres by two and a quarter metres by two metres, taking up a full displacement ton. These are sized to fit through cargo doors and only ships with cargo airlocks or other large entrances can bring them aboard. This is a rare feature among 100-to-200 ton ships, other than dedicated trader ships. Many take the presence or absence of this feature as the defining element determining whether a vessel counts as a 'trader ship'. Fortunately, with good packing, 14 One Cubes can often carry the same volume of cargo as a Tonner. The Tonner's slight advantage in space efficiency only matters if it can be brought aboard to begin with.

Beyond that is the '4 (Interstellar)' series, which come in a range of sizes. These containers are expected to be moved by cargo cranes, forklifts or other external measures and thus rarely contain their own lifters, although some have grav carts permanently installed. They require even larger openings than Tonners, usually only found on large cargo freighters. A small ship capable of ferrying one 4A container can often find emergency freight jobs at Class A or B starports. It is understood that the ship may try to use its remaining cargo volume for other freight or speculative trade, which is tolerated so long as the ship takes off for its destination within a day and does not make any side trips until the container is delivered. This is substantially more expensive than ordinary freight and used when the cargo cannot wait for a ship to happen to be making the run. The cost of this scales with the ship's size so these contracts are rarely given to ships greater than 200–400 tons.

Type codes designate a given container's form and purpose, and follow a simple format. The first digit represents what form a container takes: a standard box with a hinged door at one end, an open frame, or a simple pallet. The second gives an indication as to function: whether it has environmental controls, if it has grav plates installed to protect fragile cargo, et cetera. Some of the more common examples are listed here. As with ship mission codes, the second digit depends on the first for its meaning and specialist containers that do not fit neatly into these categories sometimes use multiple 'function' digits to clarify their purpose. For instance, '5' usually means 'sealed' but '55' is the opposite of sealed.

Containers vary in price by size, type and TL, from barely Cr50 for a simple 4F00/5 portable steel box up to roughly MCr0.5 for a 4A92/F that might act as a noble's stateroom. Between the metallurgy and precision required, even the simplest of these containers are rarely made to lower than TL5 standards.

4X Cargo Container Types

Type Code	Name	Details
00	General Purpose	The standard cargo container configuration. A simple box, typically corrugated, with a hinged door at one end. Not necessarily airtight.
05	Sealed	Same as type 00 but airtight when closed. Will protect against loss of air to vacuum. Has no other life support or environmental controls.
08	Solid Breakdown	Like type 00 but with no door. Typically constructed around some uniform substance, such as metal ingots, broken down on delivery. The broken-down boxes take up roughly one quarter the tonnage of their assembled states.
24	Damped Tunnel	A corrugated metal box, with hinged doors on two opposing ends. This configuration mounts grav plates in three perpendicular sides or more of the container to act as inertial compensators. This often stores fragile or volatile cargo. This container is not necessarily airtight.
25	Sealed Damped Tunnel	A type 24 that is vacuum rated, preventing contamination of the cargo.
29	Airlock Tunnel	A tunnel configuration – two doors on opposing ends – with both doors replaced with simple airlocks. These exist for the sake of easy transport for colonial assets, assembling facilities on-site from standard-sized components.
30	Powered Box	A box with one door which has starship-grade power feeds. Often used to ship things that need continual power, such as specialised life support.
32	Controlled Environment	Same as type 05 but has environmental controls, capable of maintaining any temperature between -35° and 50°C. Often used to refrigerate fruits and vegetables.
47	Powered Side Door	This configuration includes the power feeds of type 56 in a vacuum-rated container, with a folding door mounted on one side. This configuration is sometimes utilised by Q-ships, disguising weapon mounts as externally mounted cargo containers.
50	Open Top	Type 00 with no door and the top panel removed. Used for grain or other particulate cargoes. Some use it as an ad-hoc animal pen if they cannot afford a more secure solution.
55	Open Frame	An open box frame with structural cross members. Typically used as frames or scaffolding.
56	Powered Open Frame	This is a type 55 with extensive power feeds that are capable of conducting starship-scale power loads. This configuration often houses a fusion reactor or heavy equipment.
70	Tank	An open frame with a cylindrical tank used to transport fluids and gases. Not rated for greater than one atmosphere of pressure.
72	Reefer Tank	Type 70 with environmental controls that can maintain a temperature range outside of -35° and 50° C.
75	Sealed Tank	An open frame with a cylindrical tank that can handle much higher pressures than the more common type 70.
90	Habitat	A stateroom, office or other liveable space in a box. Type 90 bears little to no environmental controls or life support of its own and rarely contains freshers.
92	Controlled Habitat	With dedicated environmental controls, full life support and vacuum rating, type 92 is often configured as a full-fledged stateroom if sized 4C or, if 4B or 4A, one of higher quality commensurate with the space provided. This configuration can handle a temperature range of -35° and 50°C and has standardised waste disposal and water hookups alongside its power feed.

4X Cargo Container Sizes

Size Code	Dimensions in Metres	Displacement Tons
4F (One Cube)	1 x 1 x 1	Approximately 0.074
4E (Tonner)	3 x 2.25 x 2	1
4D (Triple Three)	3 x 3 x 3	2
4C (Double Triple Three)	3 x 3 x 6	4
4B (Triple Triple Three)	3 x 3 x 9	6
4A (Quad Triple Three)	3 x 3 x 12	8

LINES, LINERS AND TRADE ROUTES

When referring to starships engaged in merchant work, a 'line' is a long-lasting trade route with known characteristics and predictable demand. This demand might fluctuate over the course of years but are steady overall. Not all lines are inherently profitable and new colonisation efforts or long-term disaster relief can require consistent supply lines without much potential for profit. These use the same ships and operations but pay for them differently. Many local governments will subsidise these lines to ensure adequate service to worlds that require consistent commerce to thrive.

A 'liner' is a ship class built to service lines, which are sometimes our main audience's chief competition but they cannot be everywhere. Small ships, particularly small trader ships like the *Empress Marava*, can succeed by filling in the gaps. A reliable line going unserved by liners can be a small ship crew's ticket to retirement or to becoming merchant princes if the situation lasts long enough and the ship is able to adequately serve it.

A common mistake by many crew new to small trading ships is to see the list of cargo, freight and passenger opportunities available to their ship and mistake those for all that exist at that port. This is rarely the case at any but the smallest, least busy ports. Larger cargoes are not offered to small ships except in extreme circumstances. These are usually routine freight or passengers that have booked well in advance. Obtaining logs of cargo and passenger volumes offered to larger ships is difficult, as small ship crews rarely have a need to know and most larger ships are owned by organisations that keep this information private to avoid tipping off their competition. However, trade route maps showing the general volume of commerce between any two worlds near each other across a subsector or larger region are available.

However, not everything will ship neatly in prearranged schedules. Brokers are versed in calculating the likely prices of these cargoes at nearby worlds based on the origin and destination, as well as other factors, such as whether a world is a subsector or sector capital. Buying, transporting and selling these cargoes at a profit is known as 'speculative trading' and is the primary designated mission of countless small trading ships. Disrupting this trade disrupts the Third Imperium's economic and political power, with secondary but potentially dire consequences for its military power if left unchecked, so the most severe disruptions are often treated with the same urgency as war.

TYPES OF LINE

Lines are broken into five categories by size: major, main, intermediate, feeder and minor. Most directly link worlds only one or two parsecs apart, due to the higher cost and rarity of commercial ships that can jump three parsecs or more without refuelling. Between this and the fact that most Imperial worlds are not high population or otherwise major sources of goods, the largest trade routes only serve about a tenth of the Third Imperium and often consist of isolated pockets.

A line-like service that is sometimes available to small ships is mail cargo, consisting of data banks or small physical goods. While any ship planning a certain jump with cargo room to spare can ask if there is mail to take along, ships are more often selected if they have connections, such as prior naval or scout service and/or nobility among the crew. The main limiter is that the ship must have enough room to take all the mail ready in one go. Mail cargo should not be confused with x-mail, the higher priority mail carried by the x-boat network.

LIVE CARGO

After making sure there is adequate life support, the first step in dealing with live cargo is to load the animals aboard and make sure they can fit through the

narrowest access door on the way to the cargo hold. Certain tame animals may be led aboard via ropes and halters. However, even the most domesticated of animals prefer their freedom and may rebel as their basic survival instincts tell them not to go in the dark metal hole that reverberates with every footstep.

Some ships mount larger cargo hatches specifically to allow passage of larger animals or larger sophonts. Conversely, animals small enough to squeeze into vents or pipes should stay in enclosed cages for the duration of the trip, particularly on ships that have a free roaming ship's cat or other pet, more often for the health and safety of the pet than to protect the cargo. When boarding live animals, particularly if boarding many of the same species at once, make sure all doors and non-pathed hallways are closed or barricaded so they can only proceed in the direction intended before they come aboard. This may require temporary doors, cages, walls and crew to drive the animals where they need to be.

One example on a safari ship highlighted this problem. The ship's owner took a side job to haul 10 prime breeding cattle to another system. The first problem he encountered was that he did not set up any gates or pens near the external airlock, so the cows ran freely around the ship until his crew finally asked some local ranchers for help, who loaned them temporary barricades. Once these were set up, the cattle's only choices were to charge through waving and shouting sophonts, scale the barricades, or climb aboard the ship.

Once aboard, the cattle charged down the open hallway. Only two of them took the turn to the cargo hold and the multi-environment holding tanks. The other eight charged past and would not turn around or let the crew past. The scared cattle packed in the hallway impeded access to the staterooms and trophy lounge.

The ship's owner, thinking to outsmart the cattle and move around in front of them, used the trophy lounge to get around the cattle jam. Unfortunately, a huge male and several fully grown females were pressed against the door. Once the owner opened it, they burst into the trophy lounge. After trampling the man, they started jumping and head butting the stuffed animal trophies, not to mention excreting waste on the furniture and rugs. The room's contents, including trophies that had taken decades to collect, were destroyed and the ship's owner barely escaped with his life.

SHORT TERM

When keeping a live animal caged during a very short transport, a few hours at most, certain standards may be overlooked with little to no harm. Most animals can do without food or water for a few hours. The amount of waste that will build up in that time is minimal and can be cleaned out after arrival. The impact on oxygen reserves over such a short trip is minimal. However, temperature and the animals' general welfare must be closely monitored, with quick options to counteract natural instincts the animals may have to flee, break loose from their bondage or climb pen walls to escape.

One technique employed for thousands of years in moving top-heavy animals such as Terran cattle, horses, goats and sheep is to pack the pen to standing room only. This method works for short distance travel and allows the animals to lean on each other instead of falling over. The animals will need more cooling than normal to compensate for the extra heat.

To lower the odds that some animals will trample others, either give them enough room in the pen for a few stragglers to lay down comfortably or make multiple pens with only a few animals per pen. It is better for only one or two animals to accidentally step on a downed animal than for 10 to pile up on one in a corner. The best option is to tie the animal's head so they cannot turn around and let them have a stable to themselves, just long and wide enough for them. Systems with moderate to high technology worlds which see a lot of interplanetary livestock transport often have rentable or purchasable self-configuring pens for this purpose.

Animals being transported may show signs of stress such as wide eyes and a tendency to flee or back away from handlers. In many animals, signs of overheating involve heavy breathing or sweating, while being too cold results in shivering and shaking. Fortunately, most ships' environmental controls are easily adjusted to provide comfort, so long as care is taken to see whether warmth or cooling is needed.

LONG TERM

Jumps from star to star take more than a few hours and some in-system trips take longer, too. There are two general options for long term transport.

The first is low berths. Non-sophonts are routinely given less detailed care than sophonts and if a bull destined for breeding then slaughter gains amnesia about his life before the low berth, rarely does anyone involved notice. Low-quality mass berths that resemble stables are the typical solution. Some live cargo hauling contracts include portable low berth stables, to allow the use of ships that have open cargo space but not dedicated livestock support equipment, although the ship must either supply power for the low berths or the contract will include a portable power plant and fuel.

Not all animals are compatible with low berths. Some simply will not survive or have physiologies that low berths do not affect, while others change essential qualities. Many Aslan claim to be able to taste whether an animal was in a low berth recently. Breeding, endangered and high value animals are often not put into stasis unless facilities are of a high enough quality to guarantee they will reawaken without complication.

For live animals not in stasis, feedstock, bedding and waste handling are vital but allocating suitable space for the pens must be done before the animals are loaded. Animals require space to move around during transport. Making the pen's length and width – including feed bins, water troughs, bedding, and other supplies – 150% of the longest dimension of the animal is typically sufficient for one animal. This rule of thumb allows animals to turn around and find a comfortable spot in the pen to lie down.

For instance, a typical Terran cow that is a metre wide and two metres long can comfortably rest in a square pen that is three metres by three metres, although it is common to put two cows into a pen of that size. Giving a pen this large to just one cow is analogous to providing a luxury stateroom and usually sees commensurate upgrades to the facilities. This is sometimes done for prized or show animals.

FEEDSTOCK STORAGE

Even animals in low berths may be sent with feedstock, as most low berths slow but do not completely stop perceived time. Unlike a sophont who knows what is going on and may choose to nap away the time, an animal will be hungry and seek to eat. Awake animals are drawn to edible objects, meaning all feedstocks must be stored away from the pens so the animals cannot reach it all at once. While most animals are not smart enough to open locks or find ways into securely closed feed barrels, some are adapted to obtaining hard to reach food. For instance, ancestors of Terran goats climbed mountains for the freshest twigs and grass, so climbing an outward-leaning barricade is only a slight challenge.

Some believe this is unnecessary and throw all the feed in the pen with the animals. Most animals do not have a sense of being full and will either overeat until they are sick or waste the rest of the meal to keep others from being able to eat it, even if no others are present. This is visible with grass-fed animals which, if given an entire bale of hay, may eat some then lay down or defecate on the rest, refusing to eat the wasted part, and starve. Feeding animals no more than a day's worth at a time is recommended.

As with self-configuring pens, moderate to high technology worlds that ship many animals will usually have automated feedstock dispensers for sale or rent that can handle these challenges. They can be programmed to the same degree of sophistication as a ship's door access controls and are usually able to distinguish individual animals even when the crew cannot, preventing one animal from being dispensed another's food.

BEDDING

As any crew that bumped their arm or bruised their feet on a metal wall or floor can attest, flesh next to metal is not comfortable and can lead to injury. This is the same for animals, even ones with enough fur or hide to count as armour. An animal will not be comfortable lying on a cold metal floor, especially if it is uneven, or may hurt themselves slipping and falling. Metal surfaces textured for traction reduce slippage but will be harder to lie on, which is why some kind of bedding is recommended in cargo bays with metal floors.

Bedding can be created from a variety of composites. First, it must not be harmful to the animal, as it will probably attempt to eat its bedding at some point. Second, it must be soft for the animal to lie or stand on. A grass or hay solution is common as it is soft and most animals either eat grass or find it not poisonous. However, this is not always available. There are composite beddings using ground-up polymer, wood or other soft, non-toxic material. Inorganic solutions are preferred as they are compatible with creatures from most worlds. Some ships use dirt dug up on the animal's homeworld, giving good traction and making the floor softer and more adaptable.

WASTE HANDLING

Animals are not usually trained to use freshers and the bigger they are, the more waste will be generated during transportation. If the trip requires multiple jumps before the animal is unloaded, automatic cleaning and waste handling facilities are highly recommended. The waste handling must take into consideration the type of bedding that was used as it may require changing during the trip. Most waste can be washed away with pressurised water into the ship's recycling facilities but some may require manual removal. Some may think that regular waste removal is unnecessary but it maintains the value of animals by keeping them clean and healthy. A buildup of waste can cause problems.

NON-ANIMAL LIVE CARGO

Live plants are typically shipped in environmentally controlled containers that regulate heat, water, soil and atmospheric conditions, containing any pollen or other emissions from the plants or products used to keep them alive. Some containers require occasional opening for specialised feeding and watering during a jump. It is prudent to add a 'maintenance' charge, have the customer provide the food and obtain the feeding and watering instructions if asked to ship freight with this added requirement.

Passengers, whether in low berths or in staterooms, are not 'live cargo' and should never be referred to as such, even if they fit some definitions of the term. Neither does the term apply to crew who perform little to no function once away from port; for those, see Brokers and Other Supercargo on page 122.

CARGO HANDLING OPTIONS

Any ship that often handles cargo can benefit from special cargo handling upgrades to make the crew's job easier. Especially with smaller ships, these tools can optimise cargo handling, so the crew does not have to rely on starport stevedores to load or unload cargo. Many crews find other, creative uses for the cargo handling devices covered here such as joyriding through a cargo bay, which happens despite being officially disapproved of by most captains and ship owners.

A crane mounted to the ceiling of a cargo hold can stack cargo neatly, maximising storage space. However, the crane is not the smoothest movement for lifting volatile cargo, which is best moved on a grav cart to stabilise its ride aboard the ship. A loading belt makes loading and unloading easier, especially if extended throughout the floor of a cargo bay to its innermost corners. While some spaceports have a mobile version available for unloading, most crew dislike waiting around and insist on taking care of it themselves, sometimes causing issues such as strained muscles or crushed crew members.

Cargo ramps or airlocks can further assist in moving cargo by providing superior access, at the cost of creating another ship entrance to secure against boarding parties and the increased maintenance these demand. The *Empress Marava*'s dedicated cargo airlocks help its trading missions, so few owners remove these side airlocks to leave only the rear cargo hatch. *Animal*-class ships used primarily for hunting megafauna are often refitted with cargo doors and more airlocks to streamline loading live animals into

SLAVE CARGO

Slavery is illegal in the Third Imperium. Some say the primary reason is moral, as slavery involves denying the basic rights of sophonts. Others say it is practical because tolerating slavery undermines the free trade that is the lifeblood of the Third Imperium. Regardless, it is a practice that has persisted despite the Ministry of Justice's efforts, as assisted by the Imperial Army and Navy.

If you are recruited to crew a slaver ship, it is best to escape to port or another ship as soon as possible. Otherwise, you are likely to be made a slave over time. If you have escaped slavery in the Third Imperium, notify law enforcement as soon as possible, especially since this lowers the chances that your former would-be masters will attempt to reclaim you. It is rarely possible to notify law enforcement before escaping, so focus on getting to safety first.

If you or those who listen to you are considering becoming slavers, an honest examination of the facts should make it abundantly clear how bad a decision that would be. Slavers are chased by bounty hunters for considerable payouts by the friends and family of those they sought to enslave and Imperial authorities authorised to execute without trial. Any tramp traders or pirate groups that appear interested are more likely to try to cash in on the bounty. Most independent ports turn slavers away out of fear of reprisal. What few worlds allow buying or selling slaves are soon discovered by Imperial authorities and their governments overthrown. Without support from a substantial polity, new slavers are hunted at every stop, struggle to make ends meet and justify their actions to themselves, and eventually fall to retribution from those they try to buy and sell. Slavers do not last in the Third Imperium.

Those who point to the few well-known lasting examples should acknowledge that every such case has backing from a substantial military or some other means of preventing forces such as the Imperial Navy from demolishing the operation. System-level support, such as Oghma taking slaves and using military assets to defend slavers, appears to be the minimum necessary within a sector at the Third Imperium's borders. Even with such support, operations only last until someone powerful takes enough of an objection to it, as is beginning to happen to the Glorious Empire at the hands of the Aslan Hierate and Camoranian Starfighters.

If you are taken as a slave, you will eventually be offloaded to a buyer or a larger ship, as maintaining control of slaves requires enough slaves to set against each other. This is your best chance at escape but slavers know this and will do everything they can to keep you within arm's reach. If the handoff is made in obscure territory, possibly on an uninhabited world, there is little chance of a successful escape. Failing that, many slavers rely on a perception of legitimacy to ply their trade and as such will pass through starports. This is your moment.

When at port, do everything possible to separate yourself from your captor, preferably by way of starport personnel. A common method is to hide metal objects or anything that could be mistaken for a weapon on your person. This may trip weapon scanners and cause starport personnel to speak with you. Report your situation to them, which will likely result in a search of your captor's ship and your freedom. If anyone else offers to escape with you, particularly any who were taken with you and thus more likely to trust you, accept their help. Do not overly concern yourself with encouraging other slaves to escape as many will not want to as a result of the slavers' conditioning – and if you can successfully alert starport personnel, they will be freed soon enough.

the multi-environment holding tanks. Some *Animals* remove the launch to be able to load megafauna onto the ship for holding or processing. If expecting to haul cargo, make sure the ship has simple loading and unloading access routes.

MANUAL CARGO HANDLING

Some cargo is packaged in small and light enough containers that a sophont can easily carry it. Some captains only deal in such cargo, refusing upgrades that would lighten the chore of loading and unloading. Preferring manual handling is rare but there is some cargo that needs a hands-on approach due to value, security, or general lack of enough bulk to call for automated approaches.

Lowering the gravity can make it easier to move items, although keep in mind the difference between weight and mass – if an object is slow to start moving, it will be just as slow to stop. Using grav carts to isolate weightlessness to individual items, limiting the potential for chaos, is often a better approach.

GRAV CARTS

Little more than a floating flat bed, grav carts, often referred to as g/carts, are one of the most common tools seen in cargo handling. They capitalise on lifter technology, expanded on in the Gravitics chapter, to lighten the workload of a stevedore or loadmaster. Despite their ubiquity, most people rarely think about them until they are not available. When cargo needs moving, 'where's the g/cart?' is a common question, asked in anticipation of strained muscles or worse if heavy cargo is moved without assistance. Many crews that haul cargo soon learn to grab g/carts before trying to move anything more than a One Cube.

G/carts consist of a lifter array on the underside and a grav plate on top. The former is used to manoeuvre the g/cart and provide clearance from the deck, the latter to better secure any cargo against rough handling. Although the lifter array could in theory traverse almost any height, practical use typically limits them to a maximum of half a metre above the ground. The main reason is safety – a cargo crane that suffers a power failure can lock in place, preventing any damage to carried cargo, while a grav cart can only fall, damaging the cargo and crushing whatever is beneath.

G/carts are as varied as they are useful. They can be sized for anything from a One Cube to a 4A, occasionally permanently attached to the container. Well-designed g/carts utilise a series of micropressors to lift a container before slipping underneath, keeping the force even to prevent twisting.

Control interfaces vary, the most common being a slight extension that allows an operator room to stand, along with a set of manual controls. This is more crew-intensive but allows for finer control. Alternatively, they can rely on remote operation, either from a user's portable controller or a ship's computer. This allows for larger and more complicated cargo movement procedures to be undertaken by just one stevedore but presents a vulnerability that clever thieves can exploit. That is not to say it is easy to hack a grav cart. Some manufacturers take great pains to add as much security as they can, ranging from a given g/cart being limited to one controller with both password and biometric protection for the sake of three-factor authentication, to restricting grav cart communications to tightbeam.

G/carts come in a variety of styles beyond the simple cargo-moving carts and medical-use g/tretchers. Some luggage and small boxes have g/cart components built into their bottom, with either a control panel somewhere on its surface or a separate handheld device. Self-guiding styles can be programmed to go between sections of a ship to carry things for the crew, which can be useful aboard larger ships to transport reports, medicines, food and other items. When moving over grated metal decking such as catwalks, g/carts occasionally have issues of momentary imbalance due to the grating not giving a smooth, consistent surface to press against; many self-guiding g/carts take such areas slowly.

There are operational concerns with grav carts, particularly inertia. Although the cargoes it carries will become weightless, they will not become massless. In keeping with the Second Law of Motion, particularly massive containers that may take some time to accelerate up to speed will take just as much time to slow back down. Grav carts are thus severely limited in their top speed for safety reasons, although impatient crews can override them. This is the most important way in which g/carts are distinguished from microtractors and micropressors, which are handheld devices that do not have significant velocity or inertia independent of their operators.

THE COMPUTER

A ship's computer is its brain. Many of the tasks a starship performs would not be possible without a computer, most notably jumping to other star systems. Even tasks that can be done without a ship's computer are typically quicker and more convenient with its help.

It is so vital to ship operations that a ship's computer is distributed throughout the hull. The ship's computer can easily be one of the most expensive components of a ship, especially since it does not take much time at a starport to upgrade the hardware and almost no time to upgrade the software, making it a common money sink for ship owners with lots of cash but not much patience.

Each major system in a ship has its own computer, possibly multiple if the system is distributed and/or large enough, acting as secondary nodes to the ship's main computer. Certain large ships take advantage of this, upgrading secondary nodes to take some of the load off primary central processing units. This is possible but rarely done for small ships, as the result is typically in excess of what most small ships can make use of. Many small ships take the opposite approach, using virtual machines and firewalls to run virtual secondary nodes, which individually need little processing power to run a small ship's system, on the same physical hardware.

PRIMARY AND SECONDARY NODES

A ship's computer can be divided into primary and secondary nodes, the latter more numerous than the former even on small craft. Primary nodes handle ship-wide functions such as directly controlling the manoeuvre and jump drives, as well as reaction drives if present. They run supervisory software to monitor and control the secondary nodes. Secondary nodes handle system-specific duties such as life support and power distribution, as well as ancillary low-bandwidth tasks such as a passenger's game program when those are not run on personal computers. The need for these secondary nodes is driven by the ship's size and complexity, while the primary nodes scale with the ship's performance. For example, a small jump-4 attack ship with high performance fire control and automated defences has much more powerful primary nodes than an unarmed jump-1 megafreighter. The secondary nodes tend not to change without major changes to the ship's hull and thus are sometimes seen as part of the hull, so the term 'ship's computer' usually refers just to the primary nodes.

A 'node' refers to a processing unit, local memory and associated circuitry that can be compared to a personal computer in architecture. Primary nodes are usually more powerful than secondary nodes, as maintaining heat and oxygen levels aboard a small ship does not take as much computation power as plotting an orbital intercept course to dock with a highport, let alone plotting an interstellar jump.

For safety, primary nodes are at different locations throughout the ship. A typical arrangement is to have three primary nodes: one on the bridge, one in engineering and one near the ship's centre. These either rotate which is the true primary or do their operations in triplicate, using a best-of-three model to trap individual errors. While extremely reliable, this limits the ability to install extra parallel processing to handle additional tasks. This is why software that does not need to run on the primary nodes will rarely be run on them. It is possible to use supercomputers with substantial parallel processing power as consoles separately from computers used to control the ship's systems and some science ships do this to run complex analysis software that only needs to draw data from the ship's sensors, not to control them.

Jump Control software has proven remarkably resistant to compression, with known expansion as it becomes capable of handling longer jumps, so it became a standard by which spacecraft computers are measured. Most starships have no use for more than the minimum computer needed to run their Jump Control, as it only runs when entering jump, freeing computing resources for other tasks at other times. Ships that might want to do something else while entering jump, such as ships expecting to fight their way to the jump limit, will have higher-powered computers to run Jump Control and other software simultaneously.

SHIP SOFTWARE

While similar in concept to communications, editing, entertainment and other personal software, the programs that run on a ship's primary processors are

much larger and more expensive. They are shipped on cassettes or other hard media as a backup in case the executing copies become corrupted. These cassettes are also miniature computers themselves, running small but vital elements of the program. This architecture makes it harder to copy and distribute the program, or run multiple copies of the same program on the same computer, without paying licence fees to its maker. Although art, poetry and other forms of creative expression have protections in the Third Imperium, software must protect itself. While software can still be pirated in theory, in practice it is usually more reliable and less expensive to buy more copies if needed. This is only true of software designed to run on ship's computers; programs designed for personal computers have less protection.

Like most software, ship's software that comes in multiple versions is named in the 'Function/Version' format. In some cases, the benefits of higher versions are clear. Jump Control/X can control jumps of up to X parsecs but while Virtual Crew/2 visibly outperforms Virtual Crew/1, the specifics of how it does better are a little more esoteric. As with other software, ship's software without a listed version number has no other version. Manoeuvre software might differ from ship-to-ship but the basics are the same, with no appreciable room for improvement without upgrading the drive hardware it controls.

Several basic programs come standard with any ship's computer. Software to control the engines is necessary, as is basic interface and navigation software. Communications software capable of interfacing with every relevant data encoding standard is free thanks to the backers of those standards and almost all ship's computers have basic reference libraries. Many are extended at the whim of the crew, downloading large and freely available packages from starports. There are paid library extensions as well, most of them for specialty research with limited audiences. Secondary nodes come with standard software, from door control to life support to power plant management, while software to coordinate and interface with these nodes comes with the main computer.

The practice of wide, free distribution of communications standards builds on thousands of years of Vilani practice. Software-controlled communicators that can easily convert between known communication standards are typically TL8+ and devices at TL7 or lower may only work on their world of manufacture without significant reconfiguration. This is not a problem for starships, aside from a few extreme low-tech prototypes. It is something to keep in mind when buying discounted low-TL personal gear, however.

This practice extends to clock synchronisation. Standard transponder beacons, part of traffic control in most systems, broadcast local time so incoming ships can adjust their clocks upon jump breakout. Where these beacons are not present, standard astrogation software can deduce current time to within a second as part of confirming the ship's arrival. Ships that do not jump for a while typically automatically sync their clocks every week, before even a millisecond's drift can set in.

While software can be backed up easily, foiling run-once-and-self-erase schemes some software engineers use to milk unwary ship owners, there is some software that becomes useless after a certain time due to external factors. The most well-known of these are 'jump tapes', which allow a ship to operate without an astrogator but are only useful for about a week after creation, since the data they are based on quickly becomes obsolete.

CONSOLES AND CONTROL PANELS

Many sophonts only ever see these together and so use the terms interchangeably. However, given the wide variety of control schemes for starships across Charted Space, some formal standardisation of terminology is useful.

Technically, a 'control panel' is the direct interface to some system or device, often switches and/or analogue controls. A centrally located control panel that houses many different direct interfaces may have banks of indicator lights showing the current status of each switch. A 'console' is a device that interfaces between a user and one or more control panels. Often, consoles connect to multiple control panels to turn devices on and off remotely rather than the user having to run between control panels. A console is usually a small, dedicated computer that provides a more user-friendly interface.

Some devices do not have user-accessible control panels, only being controllable through consoles. In these cases, the plugs and interfaces through which the console communicates are considered the 'control panel'. There is usually a stripped-down console that can be plugged in for diagnostics, sometimes a single one intended to be swapped between systems during maintenance.

A console can be physically installed on or near a control panel, in another part of the ship such as the bridge, or carried around for remote access, which helps determine the type of console it is:

- **GENERAL CONSOLES** are installations too large to carry by hand, typically fixed in position, using their size to present easily accessible information and options. A ship's bridge is primarily a collection of general consoles, although these can appear throughout a ship.
- **PORTABLE CONTROLLERS** and **HAND CONTROLLERS** are devices that grant remote access to the ship's computer, hand controllers being roughly hand size or smaller while portable controllers are anything larger, typically arm or chest size. Portable controllers do not have direct access like a general console but usually have a full keyboard and screen. A hand controller is not as powerful but has the advantages of versatility and size.
- **A SYSTEM CONSOLE** is an interface between two computers so they can interact and perform tasks in tandem. A system console is helpful for complex algorithms that take more processing power than one computer can do alone. It can link remote computers so a user can control components on both. Usually, this requires a hard-wired connection.

The most common ship-duty-related use of neural augmentations is to run console software. These equate to other consoles depending on how distracted the user is while interfacing with the ship. Being able to engage in a firefight unhindered while using neural console software is comparable to a hand controller. Merely being able to walk around while using it is like a portable controller. Anything beyond that is effectively a general console. Technically all neural consoles are system consoles, linking the 'computer' that is a sophont's brain to the ship's computer.

General consoles are further categorised by type of use:

- **WORKSTATIONS**, intended for use by crew only, allow the user to interact with the ship's computer and pull up data that can be customised for the user's needs. These consoles give information about the entire ship and access to control panels throughout. They are most often found on the bridge and in staterooms.
- **PUBLIC DATA STATIONS** are akin to workstations but intended for passengers and guests. They allow for basic information to be pulled from the ship's computer, unlike the tertiary nodes sometimes provided to passengers that have no access to ship systems. This information is typically limited to expected times of arrival, atmospheric conditions aboard ship and the ship's schedule, although some will have information on the power plant or similar systems available in hope of soothing nervous passengers. Some have access to read data from the ship's sensors, particularly on science ships where 'passengers' are there to gather data and perform analysis.
- **OPERATING CONSOLES** are technical interfaces dedicated to a device on the ship. The most well-known operating consoles are often found in a ship's engineering section, being used for sensors, jump drive, power plant operation and maintenance. Sometimes a lost crewmember or passenger will complain when they cannot access the music library on the main computer, not realising they are on a console dedicated to only one system aboard the ship. An operating console

is connected to every control panel that runs the function it is set up for, usually having the most up-to-date and detailed information available. This is perfect for precise timing or minute controlling of the item, such as running jump entry sequences.

- **CONTROL CONSOLES** add task-specific control hardware and/or displays to a general console. Pilot and turret controls are common examples. When this approach is used for a captain's or fleet commander's dedicated station it is called a **COMMAND CONSOLE**. The console is usually composed of a mix of buttons, switches, joysticks, pedals or even steering wheels as the user requires. This can include full-body interfaces with haptic controls for a truly all-in-one system. Another type of control console centres around a virtual reality headset, taking over a user's perceptual space while in use.
- **DESIGN CONSOLES** are technically just a subtype of control console or command console, focusing on large displays or holographic volumes with which a user can interact. Voice control is a common secondary input channel so these are rarely seen in areas with multiple consoles such as a bridge, instead appearing in isolated rooms where one or a few users will work on one task.

Most consoles are customisable and shipyards typically have a number of styles available. Although not as popular, some ship owners prefer the tactile feel of pressing buttons and flipping switches and will pay extra when replacing a worn-out console to obtain a refurbished one of the same type. Most modern ships come with holographic displays or touch screen consoles adaptable to a wider range of users. There are a variety of 'dynamic configuration' standards which allow users to easily customise consoles as they like.

These configurations can take advantage of different senses. Controls for most human ships are oriented around visual and tactile feedback but some species like to take advantage of their auditory processing capabilities. While everyone may be familiar with alarm sounds, auditory control systems add beeps, pings, hums and musical notes to indicate the status of equipment on board. Aslan engineers are well known

ASLAN CONSOLES

The art of adapting consoles with varying amounts of options is taken to extremes on ships designed for culturally traditional Aslan. Males prefer simplified controls where one push of a button can perform all the tasks in a sequence such as sensing enemies, auto-targeting and firing on multiple targets instead of handling each action individually. Female Aslan favour larger and more detailed control panels that minutely control every aspect of the same sequence, finding they can sometimes beat the computer's response times. This is a cultural preference, not biological, since Aslan who adhere more to Imperial culture typically use standard technical options.

There is extensive Aslan literature noting the parallel between the nature of programming interfaces, translating between short information-dense displays with symbols the programmer understands and long equations using the few basic symbols the computer understands, and the contrast between female and male console controls.

for this and are often quite proud of knowing the status of the entire ship simply by listening. Dolphin ships take this a step further and can generate an entire tactical display of the ship and its surroundings.

Some consoles control and report on many aspects of the ship at one time. Others are simplified for basic operations, allowing the computer to execute multiple commands at the touch of a single button or command. A simplified sensor operator's console might display the result of a general scan around the ship that is always running when the ship is not docked, whereas one that is set to be more technical will give options for scanning a specific area of space, picking which sensors to use, and configuring power levels and frequencies to monitor.

COMPUTING HARDWARE

Ship's computers run on the same basic principles as any other. There are a variety in use across Charted Space, with Tech Level variations and local preferences, although the hardware can be distilled into six general types:

- **ELECTRONIC** computers have electrons directed within circuits. These circuits are primarily metal, with electric fields changing how current flows through certain points. For instance, an electronic touchscreen interface changes its electric potential at the location touched, which triggers the nearest sensors. Most computers are electronic and are vulnerable to electromagnetic pulses, unlike any other type.
- **PHOTONIC** and **FIBRE OPTIC** computers manipulate photons in light channels. These light channels act as circuits, although they are typically some sort of translucent crystal where optical properties can change based on the intensity of light or electric signals.
- **FLUIDIC COMPUTERS CONTROL** liquids or gases flowing through miniature pipes and valves. Fluidic devices are sensitive to temperature variations.
- **MECHANICAL** computers use clockwork gears, cams, levers and springs. These are invariably the largest, with higher maintenance costs to replace worn-down elements. Although they can be produced at lower Tech Levels, the results are rarely practical beyond relatively basic mathematics.
- **POSITRONIC** and **QUANTUM** computers use the flow of subatomic particles within carefully micro-engineered three-dimensional structures. Processes that require selecting from large arrays of possibilities or learning over time are easier to implement on this architecture, although traditional programming techniques are more difficult. Early quantum computers are programmed like electronic ones but positronic ones more often restructure themselves over time to learn. Learning computers must be trained more than programmed, so they are often flooded with large sets of data as part of their creation. Cymbeline transponder-brains are an example of this.
- **BIOELECTRIC** computers use chemical decision gates, prompted by electric potential delivered by living neurons. This is how most sophont brains work. For this reason, those who make these computers walk a fine line to make sure they are not creating anything that could be legally considered a sophont. Traditional programming techniques are all but impossible on this architecture. Like positronic devices, bioelectric devices can learn, so they are trained for their tasks.

> Do not try to use an existing sophont's brain as a bioelectric ship's computer. Those who try this tend to do so out of an obsession with cutting corners and short-term cost savings. They ignore that most sophont brains are incapable of the scale of computation needed for even Jump Control/1, without significant augmentation. The brain winds up as a permanently installed crew member, often one that did not volunteer and consequently hates whoever caused its condition. Giving a starship the ability to hate and then becoming the object of its hatred often leads to a reduced life expectancy. Further, in the Third Imperium such involuntary installation is treated as a form of slavery, resulting in lengthy incarceration or execution of those responsible.
>
> Those who actively wish to 'become one with the ship' should consider neural augmentation instead of direct internment.

HOW COMPUTING SOFTWARE WORKS

Not everything is processors. Data comes from somewhere and goes somewhere as input and output. Any program is limited to acting on the input it receives and acting via the output allowed. A simple TL7 hand calculator lacks the ability to explode or fire weapons. In all cases, computers are highly complex systems built out of basic elements, where processes and data can be considered separate from the hardware. Most familiar to Imperial readers are architectures built upon Boolean logic, a Galanglic term deriving from the Solomani phrase for basic binary logic, reinvented countless times over the ages.

The general theme of how computers work is 'staggering complexity built up from basic operations'. The basics of Boolean logic illustrate this and provide a basis for understanding how computers think. Given the extensive controls on any starship, knowing the basic thought processes of what keeps things from killing the crew can be useful.

Boolean logic deals with variables that are either true or false, often depicted as 1 or 0 respectively. This is the basis of many electronic, photonic, fluidic and mechanical computers, although it is not commonly used for quantum or bioelectric ones. There are three basic operations:

- **NOT**, represented by ¬: Takes one input and outputs its opposite. If x is 1, ¬x is 0. If x is 0, ¬x is 1.
- **AND**, represented by ∧: Takes two inputs, true only if both inputs are true. The only time x ∧ y is 1 is when both x and y are 1. If either or both are 0 then x ∧ y is 0.
- **OR**, represented by ∨: Takes two inputs, true if either or both inputs are true. The only time x ∨ y is 0 is when both x and y are 0. If either or both are 1 then x ∨ y is 1.

However, this can be reduced to two basic operations: x ∧ y = ¬(¬x ∨ ¬y) while x ∨ y = ¬(¬x ∧ ¬y). Since 'x ∧ y' is easier to read and work with than '¬(¬x ∨ ¬y)', sophonts just write 'x ∧ y'. Computers, not caring what is easy for sophonts to work with but wanting a minimum of different symbols to deal with, read it as '¬(¬x ∨ ¬y)'.

Other symbols encode more complex operations such as XOR, represented by ⊕: True when exactly one of its two inputs is true. Again, 'x ⊕ y' is what sophonts see, while computers read it as '(x ∨ y) ∧ ¬(x ∧ y)'.

Computer programs, which are sets of instructions that tell computers how to do things, take many layers of this piled on top of one another. These layers produce values that are compared to other values, resulting in certain actions being taken or not taken. This is sometimes written as, 'IF (comparison) THEN (action) ELSE (other action)'. For example, assuming x and y are each either 0 or 1, adding x+y works out to be this: IF (x ∧ y) THEN (output 2) ELSE IF (x ∨ y) THEN (output 1) ELSE (output 0). In Anglic that translates to, 'if x and y are both 1 then x+y=2, otherwise if either of them is 1 (which means the other is 0) then x+y=1, otherwise (if both of them are 0) x+y=0'.

To give a more practical example, one that shows how simple-to-sophonts operations are complex for computers, take a relatively simple door control program. When someone approaches a door that should open for that person, the computer must recognise that a person-like object is approaching the door AND that object matches a recognised person AND that person is approved to access this door.

- Recognising that a person is approaching a door means checking the input from a camera to see if the image the camera is reporting is of a person-like object.
  - This requires checking to see if it is time to see if a person-like object is detected near the door.
    - This means comparing the current time to the time the last check was done. If it has been long enough, run a new check and update 'when the last check was done' to the current time.
  - The camera's computer needs to know what a 'person-like object' is. This typically matches a heat signature of the approximately correct size and temperature, which means that a simple printed picture of a crew member will not fool the camera.
- If a person-like object is approaching the door, check the object's details and compare them to all known crew. This comparison does not care about anyone who is not part of the registered crew or passenger list, nor does it care about recognising if the thing is not a person at all: IF (the object is not a known person) THEN (leave the door closed).
  - This requires there to be a database of known crew and passengers as well as a means of transmitting data to and from said database.
    - Which requires protocols for encoding data from the camera and its computer to the database. See **HOW COMMUNICATORS WORK** starting on page 67 for a sense of the levels of detail that entails.
  - This requires an explicit list of things to compare: height, ratio of eye sizes, nose shape and size and more. This must be explicitly defined or the computer cannot deal with it.
    - The longer the list of things to compare, the slower the computer takes to cycle through them. Identification badges with a transmitter, barcode or similar are standardised in a way that living bodies are not, although it is easier for an unauthorised user to swipe a badge than to swipe a body part. This simplifies the checklist, with a corresponding trade-off in security.
  - Some door control programs alert the bridge if a person-like object that is not someone who is supposed to be aboard is detected. If a piece of cargo keeps registering as a person-sized object approaching the cargo bay doors, some crews add it to the 'known persons' list with no access just to keep it from triggering alerts.

- Once all of that is done and the individual identified, go through the list of people approved to access the door. IF (any of them match) THEN (open the door) ELSE (leave the door closed).

All the above, including many further levels of detail omitted here, is done in a fraction of a second. Those crew who configure the access lists only need to think of it as 'door control' and need not consider all these layers.

Tricking the cameras into thinking there is a person-like object with features matching an authorised person will open a door. To counter this, the cameras are difficult to deceive and the list of features is hard to fake. Likewise, eye injury or an eye-covering mask may prevent a door from opening for an authorised person, instead alerting the bridge to an unrecognised person-like object. This feature can be disabled for a costume party or when the crew is wearing vacc suits that do not show their faces well. Some ships assign permissions to certain vacc suits with easy-to-recognise identifiers, assuming that only their assigned person will wear them.

SECURITY

Despite the centrality of a ship's computer to its operation, there are those, especially from low-TL worlds, who dismiss the importance of cybersecurity, focusing instead on securing the actual ship. Likewise, there are those who believe that sufficient cybersecurity can guard against any threat, remote or physical. They are both mistaken. Computer security and physical security are intrinsically linked – when one fails, the other is soon to follow.

CYBERSECURITY

Cybersecurity is the art of keeping computer systems secure. The three basic principles of cybersecurity are:

- **AVAILABILITY:** Information should be available to those who are supposed to have access to it.
- **CONFIDENTIALITY:** Information should not be available to those who are not supposed to have access to it.
- **INTEGRITY:** Information should be correct and trustworthy, protected from corruption and unauthorised changes.

It is easy to overbalance confidentiality over availability or vice versa. Such a system should not be considered secure and usable. It does no better to forbid anyone, even a ship's engineers, from ever starting up the ship's main power plant than to allow anyone, perhaps a pirate on a nearby ship, to shut that power plant down at any time.

There are three main steps to accomplish these ends:

- **AUTHENTICATION:** Prove that a user is who the user claims to be.
- **AUTHORISATION:** Confirm or deny whether a given user has the authority or right to do a certain thing.
- **NONREPUDIATION:** Maintain trustworthy evidence of what each user did.

Likewise, most attacks are along one of three lines:

- **FORGERY:** Guessing or stealing someone's credentials without that user's active assistance.
- **SOCIAL ENGINEERING:** Tricking an authorised user into opening access or providing secure information.
- **CRACKING:** Exploiting flaws in the system.

While there are more insidious attacks, they are rarely encountered outside of a military context. Most small ship crew need only defend against these three forms.

Anti-forgery advice mostly falls upon those who set up and administer computer systems but an understanding of the basics can limit complaints. Most flavours of authentication use one of three factors: something the user knows, something the user is, or something the user has. If a system needs extra security, use more than one of these factors. Requiring two passwords is not much better than requiring one, but requiring a password in addition to a biometrics check or keycard is far more secure.

Media portrayals aside, good quality biometric scanners require signs of life, not just the presence of a specific body part. Aside from deterring bloody-minded pirates trying the simple solution, it is harder to forge a living organism with just the right eyeball or thumb than to print an inorganic replica of an organ. High TL biomanufacturing facilities are capable of this but even at high TLs, most attackers do not have their own factories with which to grow custom tools for each attack.

It is widely known to not publicly post access information such as passwords, except for systems supposed to be open to anyone who can see the postings. While a certain minimum complexity is needed to prevent guessing, such information should not be so complex that those who require access cannot remember it. Group accounts with shared authenticators should not be used if possible, instead assigning roles and permissions to individual accounts. If a computer uses biometrics, they should make sure to use a form that will be recognised through typical conditions, such as not using a voiceprint scanner that will not recognise a sick crewmember. If using physical tokens such as a keycard, there should be a system by which a given token can quickly and easily be declared missing or stolen.

Most people have heard the basic advice about defence against social engineering – since it directly attacks users, it is something that people must defend against themselves. Anyone who asks for someone else's password is either lazy, incompetent, or trying to break security. Likewise, if someone asks someone else to use the latter's access to do an action such as installing a file or unlocking something, the latter person must perform the authentication, authorisation and nonrepudiation steps. This is often inconvenient enough that if there will be more than occasional such requests, the requester should usually have access to do the task without bothering anyone else. Most attacks on this vector try to convey a sense of urgency, claiming there is no time to perform these steps, particularly authentication.

There is not much that most crew can do directly about cracking, as vulnerabilities come with the ship's software. Defence against this form of attack is one reason why critical ship software is often purchased from reputable vendors rather than copied for free, as reputable vendors have thoroughly tested their wares to reduce or eliminate flaws. Those who administer a ship's computer can lock down and turn off options the ship is unlikely to or should not use. For example, those who never carry large volumes of survey data or mail rarely have a need to enable high-volume data transfer. Likewise, alarms can be set to notify said administrator upon detection of unusual patterns. Naval architects or sufficiently paranoid computer administrators will often choose to isolate systems from each other to limit the harm caused by one vulnerability. The deliberate absence of connection for this purpose is known as an 'air gap'.

Attacking a computer requires some means of access. Attackers further than docking range are limited to communications with the computer and social engineering attacks on authorised users, both of which can be locked down. Attackers with physical access to a computer have more options. Many computers are configured to allow low-level access that can override all other users, only to those with physical access and correct authentication, both of which the defenders are supposed to have. This is termed 'root access'. Certain attacks taught in espionage organisations start by gaining authentication and physical access, such as by installing hard-to-detect hardware to monitor inputs to obtain passwords and provide physical access to users who are not themselves physically present.

If keeping an attacker out of a computer fails, a common last-ditch response option is deletion and recovery. If a ship's computer's data is routinely backed up and these backups are secure, the data can be restored from the latest backup after removing the attacker. This requires setting up a backup system, making sure the backups happen and keeping them secure. Most shipyards set ship's computers to do this automatically, so the administrator merely needs to know how to restore from backup if necessary. When buying a used ship, it is a good idea to make certain these backups have not failed or been deliberately disabled. It is customary to delete old backups upon transfer of ship ownership, as former owners should no longer have control over the ship.

PHYSICAL SECURITY

Door locks are sturdy enough to resist bashing in and difficult to unlock without tricking their control circuitry but they also alert the bridge if they think someone is attempting an unauthorised bypass. Once the computer identifies someone in need of apprehension, it is almost impossible to escape tracking while aboard the ship. Cameras and microphones are not the only tools to do this – even hiding in a low berth or cryoberth is logged and recorded. Also, atmospheric monitoring can find people hiding aboard. Iris hatches and particularly sensitive doors have sturdier locks, whether to deter theft or give crew more time to react.

Video and audio recording comes standard in all rooms except staterooms and can only be cut off with permission. Most staterooms do not have cameras for privacy's sake, but cameras and microphones outside can usually pick up evidence of any crimes that happen inside, given the short list of acts deemed criminal in Imperial space (murder on a ship is hard to hide, use of nuclear weapons even more so). Corridors or cargo holds have cameras installed in more prominent areas to provide records for thefts and cargo handling. Some cameras zoom in on any movement they detect, while others stay zoomed out to record a larger area. This video feed is saved to the main computer, both for current reference and documentation of incidents. Some ships wipe the recordings every week or month, while mission-oriented ships keep recordings of an entire operation as a log for their employers. Very few ships deliberately keep logs for more than several months, although if automatic log deletion has been disabled, security recordings can stretch back for years without significantly impacting data storage.

Video security ties into the door and iris valve security system, and much of its concerns tie into cybersecurity, particularly in availability and confidentiality. A captain can remotely lock and unlock all the doors in the ship or give and revoke access to sensitive areas. Any crew to whom the captain gave administrative access can

do this too, although captains should be aware that crew will often seek to make things more convenient to themselves, even at the expense of security. Most small ships give access to each door either to all registered passengers and crew, all crew members or specific people, with the captain having non-overridable access to all doors. Large ships have more fine-grained access patterns reflecting their needs, for example giving drive compartment door access only to officers and the engineering department rather than the entire crew. If there is a pet such as a ship's cat, that pet will usually have its own door access list.

Drawers, cabinets and specific systems can be secured via the same controls. External sensors tie into the ship's security, telling the pilot how close they are to landing, the captain who or what is getting close to the ship and alerting the crew to incoming attacks. Shipyards have a wide variety of security packages available.

The captain's access to open any door on the ship is a failsafe, programmed separately from primary door configuration routines in case of mutiny or, more often, computer malfunction. The captain's access should be as secure as the primary door configuration routines, otherwise this becomes just another weakness for attackers to exploit. Cheap, relatively low TL electronics can defeat voiceprint access and requiring biometric access is common if scanners are installed on most doors anyway. If not, a passcode known only to the captain is typical.

While limiting access to key areas is important, the default setting for internal doors during a power outage is to be unlocked. This default setting can be overridden but this is very rare on any ship with a sensible captain – emergency situations where access is needed to save lives are more common and often deadlier than boarding actions. Most doors, particularly iris valves, have redundant power feeds to frustrate attackers and booby traps involving environmental hazards or explosives are uncommon on small ships. Traps involving gravity and depressurisation are more common, as they stem from standard systems.

In deciding the best security measures for the ship, focus on who should access the area. If it is an area like the commons then open access is best but limit what functions are available in case a passenger tries to use a crew terminal. The bridge has higher security on the door than the computer terminals, as those who have access typically have authority over the ship and may need unhindered access to its systems. A cargo hold may have tight security measures near the doors for loading and unloading, with only a few cameras in the hold. A captain may want to appear welcoming to his crew and leave his office door open but may have biometric scanners on the drawers of the file cabinets where they keep the ship's important papers.

Whatever a ship's security, it is best to keep valuable data, computer access, items and cargo away from people who may steal it. If a captain is in doubt about a crew or passenger, the captain should limit their access

to the ship's systems before a problem can occur. Most computers are set to automatically recognise hostile boarding parties, locking all doors and terminals in their path. High-value cargo can be hidden behind doors that close flush with the walls, though care must be taken to shield them from pirates' sensors.

STOWAWAYS

Stowaways present a special case of physical security, as they are usually not hostile – although some are, pretending to be innocent until they can hijack the ship – but consume life support that was not budgeted for and present safety concerns, sometimes legal liability.

It should be standard practice to internally scan a ship before or just after departure from port, to check for stowaways, wildlife, contaminants and anything else the ship may have unintentionally picked up. In particular, landing gear wells should be checked. Cargo containers should be inspected upon acceptance or loading, to verify cargo and look for hidden extras. Make sure that all passengers who were onboard upon arrival have departed before leaving port, save for any who booked passage for the next leg of the ship's voyage. In addition to security measures to prevent unauthorised boarding – it is easier and safer to prevent stowaways than to deal with them – all entrances and exits at port should be logged, with a tally run before departure to flag any discrepancies. It is best practice to automate these checks to make sure they always happen. Manual double-checks are routine on large ships, although small ships often do not have the crew to spare.

Once underway, excessive oxygen consumption is often the first sign of a stowaway and can give a rough idea of location. Thermal and high-sensitivity acoustic hand scanners are the most commonly available tools to track down the precise location. Stowaways encountered underway are often scared and not fully rational, having made the decision to stow away in the first place, so an empathetic but cautious approach will produce better results than threats.

Remember, stowaways begin by lying to the crew by not declaring their presence. They are not friends. Although some crews think it is traditional to put stowaways to work, this is not recommended. Sabotage concerns aside, stowaways are generally untrained labour, often still getting used to life aboard ship and much more likely to injure themselves or damage equipment. Many believe they have all manner of rights; while slavery is illegal, execution of stowaways is legally justified in the Third Imperium as they endanger ship and crew.

If they are discovered before entering jumpspace and a more humane fate is desired, either return to port to offload them or put them in vacc suits with a beacon, eject them and notify the local port. If they are discovered after entering jump, best practice is to give them basic passage in locked quarters – separately, if several are discovered – or low passage, then upon arrival hand them over to the Port Authority or kick them out. Whatever the resolution, if someone not aboard owns the ship, the entire incident including handling of the stowaways must be logged, documented and reported.

Stowaways who are honest, work hard if offered work and get the crew to like them, may reach their destination free and clear with a bit of pocket change, which is usually the best possible outcome.

ARTIFICIAL INTELLIGENCE

Even in organic sophonts, there are many kinds of intelligence. Skills with maths and logic are not the same as a knack for poetry or puns, while neither is identical to an ability to understand emotional cues. Some sophonts train in multiple kinds of intelligence, while others focus only on specialising in a few skills. Scientists from across Charted Space have not decisively determined how best to categorise these types of intelligence. It may be one of those things that sophontic intelligence is unable to determine about itself.

With that in mind, the categories of artificial intelligence likewise blur. However, there are a few useful distinctions one can make. These terms technically apply to non-artificial intelligences too as almost all sophonts and even sub-sophont animals have 'task resolver trained brains'.

PROGRAMS AND BRAINS

Positronic and bioelectric computers are more often trained than programmed, while other types are more often programmed than trained. Learning computers are generally called 'brains'.

While sophisticated programs can seem intelligent, their creators have anticipated countless scenarios and laid out procedures to deal with them, this list of procedures being a program. Unexpected behaviour can emerge from extremely complex procedures but this list does not change itself in reaction to input. At

most, programs can accumulate a long series of inputs and discern patterns from them but only those they recognise. For example, highly sophisticated chatbots designed to carry on spoken or written conversation can never learn to paint.

Brains change themselves in reaction to input. This allows them to learn but causes them to degrade over time. The exact means of decay depends on the hardware. The primary way that positronic brains fail is from hardware gradually degraded by miniscule antimatter-matter reactions. While there are libraries devoted to the number of ways that organic brains malfunction over time, how long they last varies. Anagathic-boosted organic sophonts have the best longevity, typically numbering a few centuries.

Brains can be further divided into 'trained', 'recorded' and 'programmed'.

A 'trained brain' may have been created with a certain configuration to give it certain knowledge and thoughts but the majority of its learning reflects changes from input data. The pre-existing knowledge and thoughts are referred to as 'instincts' or sometimes 'genetic memory', especially when talking about naturally evolved organic intelligences.

Bioelectric brains can be recorded but not positronic or quantum. These 'recorded brains' can then be replayed on other devices, typically other bioelectric brains or electronic computers. They start operations with their intended knowledge and thus are more consistent and reliable than trained brains. Most wafers are recorded brains, which is part of the reason they only work for certain genetic profiles. The highest fidelity recordings are personality wafers, while other wafers come from lower fidelity recordings. The key difference is that recorded brains stay functionally the same as their initial recordings, while trained brains do not.

Some complex pieces of software change themselves over time in response to input, making 'programmed brains'. The exact line between 'program' and 'programmed brain' is fuzzy but hinges on the presence or absence of a significant capacity for self-modification without explicit prompting or guidance. Attempts to create trained brains this way have failed – if a brain is allowed too much leeway to change itself it eventually breaks, becoming unresponsive or unusable. In practice, programmed brains act like recorded brains in most aspects, save that they run on computers other than bioelectric.

TASK ASSISTANTS, ENABLERS AND RESOLVERS

Another way to group artificial intelligences is by what they do.

Task assistants help someone to do a task. They have no initiative. When left alone, they are utterly inert. A database is a prime example. When asked a question it will answer but does nothing if not prompted.

Task enablers allow a task to be done. Some can be set to perform a task under pre-set conditions. A factory's artificial intelligence, running machines to stamp out part after part using templates designed before the factory started operations is one example.

Task resolvers can act on their own. They typically have orders to follow and other limits on their initiative but they can be thought of as additional crew. Virtual Crew software is an example, as are personality wafers.

IS IT A SOPHONT?

If it is not a trained brain, it is not a sophont. This keeps personality wafers from being accorded the legal status of sophoncy, save for 'permanent' or otherwise long-lasting recordings. Some worry that this technically disqualifies newborn natural organic sophonts. However, the amount of input they receive to reconfigure their brains to being able to independently survive quickly renders such worries moot.

If it is never a task resolver, it is not a sophont. Constant initiative is not necessary to demonstrate this, just some of the time. These qualities are necessary but not sufficient to demonstrate sophonthood. In the Third Imperium, sophonthood is a legal distinction which only the Imperial government may rule on, so any questionable cases should defer to the government's ruling. Imperial courts have a well-defined, if little used, procedure for non-sophont entities desiring legal sophont status to demonstrate they are acting on their own initiative and capable of learning. Court records show that most such cases fail on these grounds.

SDG-313F transponder-brains are a useful example. They are limited versions of Cymbeline brains, which are task resolver trained brains of sub-sophontic intelligence. SDG-313F transponder-brains are passive, so are not task resolvers. Rarely do they learn and grow significantly beyond their initial programming and their architecture is not bioelectric, making them programmed brains. Task enabler programmed brains are not task resolver trained brains. In the eyes of Imperial law, only task resolver trained brains can be

DRONES AND ROBOTS

The terms ‘drone’ and ‘robot’, although often used interchangeably, refer to two different types of automaton. The first is a shell that must be controlled by some outside force, whether that be software running on a computer outside the drone or a sophont with some control apparatus, while the latter can operate autonomously. Robots are noticeably more expensive but typically more capable. A common setup is for one advanced robot to supervise a small group of drones. Some robots may exceed the skills of even a well-trained sophont, although they are expensive to the point that it usually takes decades to recoup their cost.

Robots are limited in their ability to react to unexpected situations, which bankrupts most efforts to entirely replace sophont labour with robots. Some remark on how much continued demand exists for sophont workforces despite thousands of years of living with automation. This is the primary reason why. Automation can assist sophonts, greatly reducing the need for their labour but not completely eliminating it.

sophonts, so SDG-313F transponder-brains are not sophonts and using them does not amount to slavery, although there is not a universal consensus on this.

DRONES AND VIRTUAL CREW

A ship’s computer is a smart tool, assisting crew in their tasks or doing tasks on their behalf. Some ships take this to extremes with software packages that provide a virtual crew to handle piloting, sensor operation and gunnery, along with drones to handle tasks such as engineering that require moving around the ship and interacting with its systems. Astrogation must still be done by a sophont but some ships can theoretically fly with an astrogator alone.

Robots and virtual crews are more valuable on ships performing questionable deeds, as fewer crew mean less morals to overcome and fewer people to keep secrets, to the point that a mostly automated small ship will automatically draw suspicion at most ports. A ship controlled by its computer increases the potential damage from attacks on the ship’s computer, so any captain with a mostly drone crew needs very good computer security to keep from being hacked out of command. While there are some downsides to having a mostly virtual crew, they can make up for deficiencies in skills the crew lacks. Ships that exist to ferry a small team to their target such as special forces or a research group may have a virtual crew take care of the ship,

performing routine system checks and alerting the crew to any abnormalities, so the sophonts can focus on their mission. Virtual crew have supported many a sophont as they navigated the stars, sometimes simply to have something to talk with during the voyage.

Many of the virtual crews on the market today are designed to be portable across a wide variety of spacecraft and computers. Although this is necessary for a given piece of software to be sold at all, this does result in a loss of optimised function, as software cannot capitalise on the features of a ship if some other ship lacks those same features. Ship's brains – robotic brains built into a spacecraft's hull – do away with this restriction. As they are expected to only run on one spacecraft throughout their entire service life, they can adapt to the ship they are mounted to and maximise their efficiency. In addition, standard virtual crews do not coordinate between disparate systems particularly well. Gunnery software may have to react to piloting software's decision-making, instead of the two working together. Ship's brains can control the ship's systems at a higher level and can operate them all in concert.

For tasks that a virtual crew cannot handle, drones are a relatively inexpensive less-than-total-replacement option, useful for many functions a sophont might find difficult, dangerous or tedious. Repair drones, for instance, move throughout a ship and just outside, looking for and patching holes in the ship's hull, either remotely controlled or run by the ship's computer. They are a combination tool chest, diagnostic engine, troubleshooting assistant, ship's computer interface and helping hand. These drones are usually miniature grav vehicles interacting with the ship's gravity, although spider-like walker designs also exist. Some drones even mimic humans or have similar manipulators, to make use of existing tools designed for human-like hands.

Belt mining is another task which frequently uses drones. Laser drills are the most common mining tool, notorious for shedding copious amounts of heat in use. Planetoids are often not fully mapped, with hidden gas pockets, voids and other unstable features discovered during mining, sometimes explosively. Between those and the danger of being in space, it is much safer to operate a drone from aboard a ship than to send crew outside with a laser drill. One crew member can operate a swarm of drones, much like conducting an orchestra.

Probe drones are familiar to most who have served on a scout ship. They are miniature sensor packages that deliver value by being somewhere the ship is not. This can be for convenience, such as a drone monitoring weather on one side of a world while the ship is busy on the other or it can be for safety, dropping one into a live volcano or sending it to investigate an unidentified energy signal. To facilitate this, they are cheap and disposable. A *Suleiman's* workshop is capable of manufacturing replacement probe drones if given suitable raw materials.

Engineering robots are less common than virtual crews or repair, mining or probe drones. They are essentially repair drones upgraded with autonomous diagnostic and problem-solving software, able to run without constant direction from the ship's computer since one of their duties is to maintain and repair said computer. Running with just one engineering robot and no other mechanical talent on the crew is ill advised as when something happens to that robot the ship can quickly become stranded. Using two robots to maintain and repair each other often fails in practice as most units on the market have programs rather than brains, so they lack a sophont's ability to adapt to unexpected circumstances.

SENSORS AND COMMUNICATIONS

In a poetic sense, sensors are the eyes and ears of the starship. Just as a suddenly blinded and deafened person must take care navigating safely, a ship without sensors is vulnerable to the dangers of in-system travel. For this reason, all but the most primitive or damaged starships have a sensor package.

Certain built-in facilities on starships qualify as 'sensors', although they are not part of any sensor package. A conspicuous one is a porthole or window, by which any sophont with an eye can spot objects sufficiently large or close. Another is the closed-circuit security camera network, by which crew may monitor every surface, corner, nook and cranny of the ship. Yet another is the 'weather' sensor network attached to various points along the hull, which are simple monitors that give alerts when there is a problem with air pressure, excessive wind speed, when the ship is submerged, or if there is an unhealthy level of radiation.

Sensors analyse the physical state of a star system and collate a huge amount of detail into intuitive reporting, monitoring and alerting. Some sensors catalogue the resource potentials of unknown worlds. These form the backbone of an initial fly-through survey of a system by the Scout Service. Others can hunt out a pirate's nest by looking for minute anomalies on a planetoid's surface. Still more can estimate the complexity of a civilisation by measuring the particulates in a world's atmosphere.

THE TYRANNY OF DISTANCE

Naval battles fight at ranges of tens of thousands of kilometres. Jump drives enter and exit a system at hundreds of thousands of kilometres from a planetary surface. The average distance from one world to its nearest neighbour in a system may measure in hundreds of millions of kilometres. Only artificial senses, such as a ship's sensors, can gather useful data at these ranges.

Fortunately, space is empty. Dust and micrometeorites are rarely significant enough to occlude signals, especially within a star system. This means that it is theoretically a simple matter to see whatever interesting signal is out there if a big enough sensor is in line of sight. Even large ship sensors usually cannot detect individual ships at typical jump distances, although it is a simple matter for most starports.

Instead, most ships can only detect the outline of a sensor contact from a few million kilometres, which is often the basic information needed to classify it as a ship or not a ship. More detail requires getting much closer. Naval weapons with longer ranges would find it difficult to hit their targets, let alone confirm they were firing at enemies.

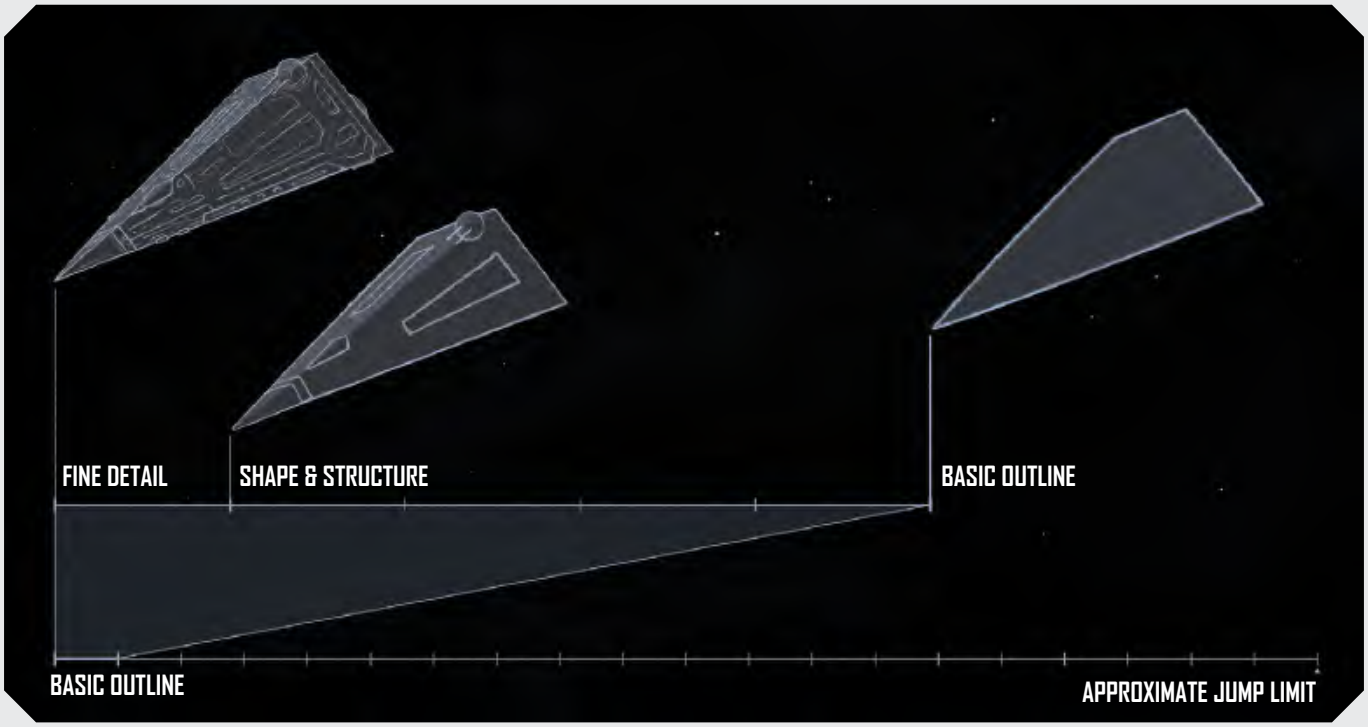
ORTILLERY SHIPS

This does not include ortillery fired at planetary targets with known locations. There exist ships designed to jump in, send munitions at a world and jump out before the planet can muster any response, hoping that local defences do not manage to detect and destroy the bombardment. It does not include missiles, which circumvent the problem by carrying their own sensors to use when they move close to a target.

AUTOMATION AND ANALYSIS

This leads to one of the main problems for sensor operators, often referred to as 'sensops'. Most of the time, sensors report the same thing minute-by-minute for days on end. It is impossible for most sophonts to give this data their full attention for six or eight hour shifts but computers can handle this task easily. However, computers can only report things a user tells them to, while most of the interesting data from sensors is interesting precisely because it is unanticipated.

Further driving automation is the sheer amount of data coming in at any given second, even on a small ship with only basic sensors. By analogy, optical sensors such as eyeballs and retinal neurons allow sophonts to input data from this book. The brain is able to handle the input of these sensors and process it into usable



information. Handling one additional set would require some adjustment but might be doable. Handling 1,000 additional sets would be overwhelming.

From the sensop's point of view, running sensors means working in concert with machines, looking for patterns and anomalies they cannot recognise within far more data than the sensop can manually process. Coming up with new algorithms and programming them into the computer on the fly is part of the process. There are libraries of time-tested algorithms one can consult but there always seem to be new problems or variations not handled by the existing code, although some sensops are particularly talented at applying existing patterns to new cases.

When this fails, many overlook or do not report anomalies. Studies conducted into how something so clear in hindsight escaped notice rarely produce any satisfying conclusion. After-action analysis usually proves time-consuming and inconclusive, even when the sensop took pains to have the algorithms explain why they made the decisions they made. This assumes the missed data did not lead to disaster – missing a hostile intent on destroying the ship tends not to leave an intact enough report to extract logs from.

When this succeeds, the invisible becomes visible. Crews can make accurate predictions and safely act upon them. This happens so often that people take it for granted, which is a testament to how well and how routinely sensors work.

HOW COMMUNICATORS WORK

One cannot simply shout across the vacuum of space. Among other problems, the lack of air does not conduct sound. To speak from one ship to another or between ship and port, it is necessary to encode communications in some other medium such as radio and transmit it, relying on the recipient to be able to receive and decode. In most cases aside from genuine first contact, both sides will possess one or more mutually understood mechanisms.

To explain radio communications simply, keep in mind three basic components: Transmitters, receivers and radio waves. This is the bare minimum needed to send a signal. Advanced systems have other components but we will first focus on these. Non-radio communicators, such as laser or meson, work by similar principles.

Transmitters send out high frequency radio waves. First, the information to be sent is turned into digital data. In the case of computer data that is already digital this is straightforward, while there are many schemes for translating analogue signals such as voice and pictures into digital forms. This data is encoded into radio wave patterns by varying the phase, amplitude or frequency. These variations are a code that only a properly configured receiver can pick up and understand. High frequency means sending more waves in a given amount of time, thus being able to send more data per unit time than a low frequency signal. Changing the amplitude means making these

waves stronger or weaker, while altering the phase means altering the timing of these waves relative to some point in time, typically the start of a batch of data.

Once encoded, the signal is transmitted via an antenna. If transmitting the signal via radio, the antenna is a piece of wire that runs an electric potential back and forth to generate alternating electric and magnetic fields. As the signal heads outward from the antenna, the receiver picks up the signal through its own antenna and decodes it back into data a computer can use. Radio receivers have antennas of specific lengths, in which alternating electric and magnetic fields of the right frequencies will induce an alternating electric potential, which the circuits of the receiver act upon. Multiple transmitters can set up overlapping fields which cancel out in most directions but reinforce in another; this is called 'beamforming' or 'beam steering' when used to reinforce the signal toward a specific recipient. Artificial gravity can create small lens-like deformations in spacetime to reinforce the signal in a specific direction or enhance signals coming from a specific direction, a process known as 'gravitic microlensing'.

Starships have both a transmitter and receiver to communicate with other ships and worlds. The transmitters will encode data for uplink to send it across the expanse of space. Receivers then pick up the signal and decode the data. In the case of radio, standard practice is to have multiple antennas, some of which are configured as transmitters and some as receivers, switching how many are on each role depending on how much the ship wishes to transmit. In the event of an emergency, most starships have a clearly visible distress signal button on the comms panel.

Encoding and decoding standards vary from region to region. Typically, a given homeworld that reached TL5 prior to interstellar contact will have developed one set of standards, that are then used by its colonies as well as nearby homeworlds that were less than TL5 on first contact and had radio standards introduced to them. One well-known example is the Imperial standard emergency distress broadcasts, Mayday and S.O.S. from Sol and Gashimeku Kaalariin, known as Signal GK, from Vland. Signal GK was known throughout the First Imperium but the Solomani signals were unknown outside of Sol prior to Solomani discovery of jump drive. These days, all three are recognised throughout the Third Imperium and beyond, although they might not all be known far from Imperial space.

Likewise, local transmission encoding standards are known and widely distributed. This is widely useful information that is free to distribute and has usually had centuries to propagate so most communications software is able to automatically detect and employ any widely used standard in or near the sector of origin. Someone crossing the Third Imperium all the way from the Solomani Rim to the Spinward Marches might occasionally need to download a software update, freely available alongside map data from any Class A, B or C starport. This is so prevalent and ingrained that any new communications standard is not widely recognised until these software updates are in distribution. Every world within a sector's radius that sees any traffic will have the update within a year. Only the scouts, who have specialised software to analyse and decrypt unknown transmission protocols, should ever be in a situation where local radio standards are initially unknown.

In some cases, the signal must go through other components before reaching the correct receiver to clarify, boost, or secure the transmission. Some planets erect antenna towers separate from receivers designed to maximise the strength of both sending and receiving, to retransmit the signal so it can reach its destination. A ship's comms may be routed through an orbital satellite network that will then direct the signal toward the receiver they are trying to contact. It is rare that its receiver absorbs the entire strength of a signal. Any significant TL5 or higher civilisation creates a radio 'footprint' from unabsorbed portions of its broadcasts, expanding out from the world. The farther away from the primary signal, the longer it takes and the more it distorts, until it finally disappears and becomes indecipherable. It is quite common for a new colony in a previously uninhabited system to be discovered a few years after founding when its first broadcasts meant for internal consumption cross the parsecs to settlements in adjacent systems. This happens often enough that new colonies that are serious about stealth will ban radio transmissions outright.

Comms within a ship use the same principle on a much smaller scale. Whether there are wall-mounted comms in one area of the ship sending signals via wire instead of through the air or if each of the crew has a radio on their arm, their main purpose is to keep the crew in constant communication.

ACTIVE AND PASSIVE SENSORS

Regardless of their operating principles, sensors split into two types: Active or passive. Active sensors send out signals – often referred to as a 'ping' – then try to detect a return signal reflected from a target. Passive sensors

do not send anything, as they detect signals emitted from targets, potentially including active sensor pings or reflected environmental signals such as sunlight.

Active sensors allow collection of more detailed information about the ship's surroundings but make the ship more visible, where passive sensors are quieter but do not allow as much information. Passive scanners can track and range most objects near a ship in space. However, the greater precision that active sensors afford and the presence of transponders render stealth useless. This means that most ships run with active sensors.

COMMON SENSORS

Most starships install standard sensor suites. A discerning ship's captain might want to know what each of those sensors does and any competent sensop should already know.

RADAR AND LIDAR

Radar is an umbrella term for a large class of basic tracking sensors. Radar – Radio Detection And Ranging – projects focused radio pulses in sweeping scans of an area and interprets the returned signals or echoes for information about an object's size, distance and speed. Lidar is an optical version of radar. Many variants exist, for optimised long range and ground penetration.

VISUAL SENSOR

One piece of equipment seldom mentioned is the scope. This is essentially a telescope, capable of seeing objects very far away, with a multispectral camera on the back end receiving light in wavelengths from infrared through ultraviolet. There is often some bias in the selection of frequencies, centred on whatever the sensor's builders or expected operators consider their primary visual spectrum. Improved gravitic lensing is one of the primary ways this gets better at higher Tech Levels, until at TL14 it becomes 'visor' technology, being much better correcting distortions that alter photons' paths enroute from detectable objects, which includes gravitic lensing.

The visual spectrum remains the predominant way to display information from other sensors as all the data in the world is useless if the crew cannot interpret it easily, and vision is a primary sense for most known species that build starships. As a result, although the raw information is still available at a sensop's console, all of a ship's sensor input typically collates into a single visual display, with different sensors colour-coded. On some ships, especially military, this information will be overlaid on viewports throughout the ship to give crew better situational awareness.

JAMMER

The jammer directly affects sensors. By distorting the ship's emissions and scrambling active sensor signals, it makes a ship harder to detect. As a result, this muddles the ship's location; others will know that the ship is there but it will be harder to hit. Basic jamming capability is available at TL10, while a countermeasures suite is available at TL13, with an improved version at TL15.

SOUND SENSOR

Another sensor group found on most ships is a set of shielded microphones. While sound does not carry in a vacuum, ships are often in enough of an atmosphere to make it worth carrying, proving especially useful in monitoring for would-be intruders while in port. Advanced models are capable of identifying a variety of sounds, referencing a vast database to discern whether a rumble from a dormant volcano was a harmless twitch or a sign of imminent eruption. Most models are capable of acting as makeshift external speakers. Ship captains have found many uses for this feature, from threatening locals away from the hull to piping out a preferred music playlist when relaxing outside.

NEUTRINO DETECTOR

A simple case filled with a transparent variety of superdense, built around a specialised nuclear damper field. Without the nuclear damper, this case would have to be much larger, well beyond what a small ship can fit. The speed of light through superdense is much slower than the speed of light through vacuum, so neutrinos moving at the latter speed are moving faster than the former. When their course takes them through the box, this causes them to emit Cherenkov radiation – typically blue light – by a mechanism similar to sonic shock waves when objects move through air faster than the local speed of sound. Early TL versions use water or ice instead of superdense but the speed of light through these is faster, although still less than through vacuum, causing the light to be dimmer and the system less accurate.

This system is crude next to what is in dedicated science ships and facilities, often picking up cosmic rays and other background radiation as interference, though it is a reliable early warning system for solar flares. It detects the presence of nearby stars as a backup for visual confirmation, such as when coming out of jump in the shadow of a large planet. It is not sensitive enough to reliably detect power plants except at very close range.

DENSITOMETER

This passive gravitic sensor maps interior or subsurface structures. The data only gives hints of structure and the resolution is poor but it can indicate veins of ore, metal deposits, caverns, gas deposits and so on. When scanning ships it clearly distinguishes between dense machinery and voids, such as staterooms and empty cargo holds, although identifying specific contents is trickier. The grav and mass sensors listed further on are specialised forms of this sensor.

LIFE SCANNER

Certain animals and sophonts, as well as psionic talents, have the ability to detect life at a short distance. Called a life detector, it is a technological analogue of that sense. It is an analysis suite, not directly detecting 'life' but rather looking for subtle patterns in infrared and signals that other sensors gather, although there is little practical difference. It is capable of differentiating and describing types of life in range. This is popular with the Scout Service, who use it to survey life on a world's surface. Often mounted to cutters utilised by station crews for rescue missions, it can locate survivors on a stricken vessel as well as be used for interdiction and inspection duties.

COMMUNICATOR

Every ship has a communication suite budgeted as part of the standard sensor package, which many frequently take for granted. Comms have simple operations, as the captain tells the computer to open communications with a ship or starport and the computer complies. Still, there are some nuances to comms known to the best communication operators, known as 'commos'. Military communications suites named 'CommCasters' can network a squadron's computers into a unified battle network, which enables devastating concentrated firepower.

Below TL15, this is usually broadcast radio, occasionally laser where wide broadcasts are not desirable. Wireless gravitic connection, known as 'gradio', is like radio but using gravitic pulses rather than electromagnetic. Gradio is uncommon as a general-purpose communicator, mainly because it requires carrying basic radio technology anyway to speak to all starports that do not have gradio. At TL15, meson technology becomes the communicator of choice, especially for military ships, although many still use radio for broadcasts. The meson communicator's ability to ignore planetary masses and most forms of interference, not to mention being impossible to intercept, gives fleet commanders better command of their ships.

These suites include transponders, which usually must be on at all times unless a ship wishes to be mistaken as hostile. Some systems allow captains to turn these off when not near a starport to avoid pirates. Recognised friendly military ships are always allowed to turn off their transponders.

Countless individuals have attempted to hack their transponders, found it more difficult than expected, wound up wrecking it and attempted to blame random damage. Authorities are so used to this that, absent overwhelming evidence, they will assume deliberate destruction to hide whatever the transponder would have shown, which by itself is grounds to seize the ship throughout the Third Imperium. Unless facing the death penalty for actions the transponder would testify to, attempting to falsify this is probably not worthwhile.

Upon 'discovering' that the transponder is 'broken' or the ship suffers severe comms damage while near a world with functioning traffic control, the legal path is as follows.

1. Improvise a signal output device out of whatever is available. It does not have to be official, just enough signal that the ship is visible and not a hazard to navigation. Switching on any active sensor will meet this requirement. Failure to do this will result in the vessel being classified as a derelict and may legally be claimed by whichever salvage crew reaches it first.

2. Proceed to the mainworld's orbit at no more than 1G while maintaining a sensor watch, eyeballs to windows if nothing else. If another vessel enters visual range and approaches, cut thrust immediately. When reaching a highport before any other vessel draws near, approach it and attempt to establish communications but do not dock without permission.

3. Do NOT land. Attempting to land outside of a downport when there is local traffic control to contact is taken as evidence of smuggling. Landing at a downport without permission may be a crime. Wait for a patrol craft. Only attempt landing in an extreme life support emergency or if given permission.

4. Expect the authorities to impound the vessel until they can confirm its past itinerary, usually within two to three weeks. Authorities will not detain the crew, as they consider the ship enough of a hostage. Most authorities quickly remove all the evidence they can then allow repairs to take place, installing a new transponder and restoring the ship to spaceworthiness.

TRANSPONDER MODES

Most transponders across Charted Space can switch between active, passive and covert modes, with military or otherwise state-affiliated ones capable of full IFF mode. The crew is never supposed to turn off transponders without full IFF, although covert mode is close enough for most purposes.

ACTIVE: An active transponder is always on and sending out pings. While the other modes only transmit directionally in response to the received ping, active mode broadcasts omnidirectionally.

PASSIVE: A passive transponder does not send out any pings but will respond if pinged. Many starports responsible for traffic control will routinely ping empty space, making this setting less than useful for sneaking up on worlds.

COVERT: A covert transponder does not send out any pings. It will only respond to pings with authorised command codes; for ships with Third Imperium compliant transponders, their codes are known to Imperium warships and licensed starports. It responds directionally, so as not to give away the ship's location to pirates. Depending on how isolationist the local world is, this may allow a ship to sneak past local defence forces.

FULL IFF: Full control of the transponder, with facilities to automatically interrogate and respond to allied ships' transponders, no matter how it is configured for civilian and enemy vessels. In addition to just turning it off fully, vessels with an IFF-capable transponder can set up false identities. At extreme ranges where a pirate ship's sensors might only have a transponder signal to go off of, this can disguise a 2,000 ton frigate as a 200 ton merchant trader to ships with lazy sensops. Full IFF is generally restricted to naval vessels and accredited mercenaries but is a standard feature on IISS vessels. This is supposed to be removed prior to them being sent on detached duty but is sometimes overlooked.

SPECIALISED AND EXOTIC SENSORS

Beyond the standard packages are specialised and exotic sensors. A ship's captain might find these on custom ships, special-purpose surveyors, military reconnaissance vessels, or alien craft.

CHEMICAL ANALYSER

Sometimes called a 'sniffer', 'multispectrometer' or 'multispec', the analyser uses an array of small spectrometers to quickly analyse the chemical profile of whatever is right in front of it, most often a world's atmosphere. From this analysis, it can provide basic information such as percentage of diatomic oxygen molecules and the presence of trace contaminants. Using this and other data, a sensop might be able to determine if a world has biological hazards, chemical corrosives or even a civilisation. It can also warn of sudden shifts, such as if a ship is about to run into an acid cloud. Higher TL versions extend how far forward it can analyse to improve the quantity of data, along with adding densitometers and other capabilities, although even at TL15 this remains far shorter ranged than the ship's other sensors. These instruments are notably poor at analysing solid materials beyond the surface layer, unless obtaining samples and grinding into dust for analysis. An analyser can measure trace gases around a planetoid or even space. Hydrographic versions exist, optimised to analyse oceans.

NEURAL ACTIVITY SENSOR

An advancement of the life scanner, this sensor can detect neural activity. Although it is largely an analysis suite, unlike the life sensor this does have some direct sensing capability, using very sensitive electromagnetic field detectors as well as direct psionic detectors. As a survey sensor, it can tell a scout crew if a world has creatures with brains and how advanced those brains are. As a search and rescue sensor, it can inform users if and where to find the injured and casualties. Certain marines and pirates use it to locate crew on a ship they are about to board, to take out all possible resistance. Some of the most bloodthirsty pirates use it to aim their ship's weaponry, killing everyone on the ship before they board to take their prize. As of TL15, this sensor is not advanced enough to imitate advanced telepathy, fictional dramas about using it as an interrogation device notwithstanding.

FIELD SENSOR

Some animals and sophonts have a sense called awareness, which is the ability to see electromagnetic fields. This sensor is its analogue, multi-spectrum detectors sensitive to electric and magnetic fields. In addition to being a backup for life and neural activity sensors, crews use this sensor for

surveys where electromagnetic fields might indicate the presence of interesting things underground, such as a soon-to-be volcano.

GRAV SENSOR

This device detects the gravity profile of objects at light-second distances. It is not effective for mapping internal structures, although it can tell if something appears to be unusually hollow or dense and sees occasional use in prospecting. It can detect the use of gravitic drives or jump entry and exit flashes; as such, military craft or starports use it to detect ships trying to remain hidden. It can detect if someone is intentionally modulating their gravitics to send data using any known encoding mechanism. Any grav vehicle engine, lifter plate or manoeuvre drive is capable of transmitting as a by-product of normal operation.

MASS SENSOR

This device measures the gravity profile of a planetary object a ship is orbiting. Unlike the grav sensor, it detects gravitic devices as large masses, often confusing a gravitic object with a larger mass. To the unskilled, a ship's boat has a gravity profile that can have the same mass signature as a large planetoid. This sensor is typically included in survey sensor packages and specialised survey drones, which rarely encounter gravitic devices other than their host ship, which can subtract this known quantity from the data.

PROXIMETER

This close-range sensor detects objects near the hull of the ship. It has two general uses, as an accurate, close-up altimeter and as an alerting mechanism when small threats such as asteroids or boarding parties approach the ship. This is typically an analysis suite tapping into visual, radar and other sensors, particularly the mass sensor if present.

RADIATION SENSOR

This is an advanced version of the basic neutrino sensor, which can detect a broad spectrum of fission, fusion and antimatter by-products. It can pinpoint source locations and level of hazard, even from orbital distances. Its primary use is to locate operating power plants.

SENSOR EMPLACEMENTS

Sensors are usually distributed on the surface of the hull, especially with civilian ships and typical sensor suites. However, there are many options depending on the ship's intended use or need.

SHIP-LENGTH BASELINE

By distributing sensors across the hull, they form a synthetic aperture array with a cross sectional area of the entire ship. This is standard for most sensor packages, as it is a simple way to gain a large detection area. On average, there is only a 10-fold difference in maximum dimension and thus maximum resolution between a 100 ton trading ship and a 100,000 ton freighter, without specialised deployable sensor booms or fleets of drones to act as a distributed sensor. These ship-wide units are invariably arrays of identical detectors that, like the portion of the jump drive distributed over the hull, can be individually tested and replaced as needed. Even the most basic sensors distributed over a 10 ton smallcraft hull pull in a lot of data per second, more than a sophont can process all at once.

DISH

Some survey vessels and recon ships use dishes to collect sensor data. These take up volume and cost but provide better data to the target sensor.

ANTENNA

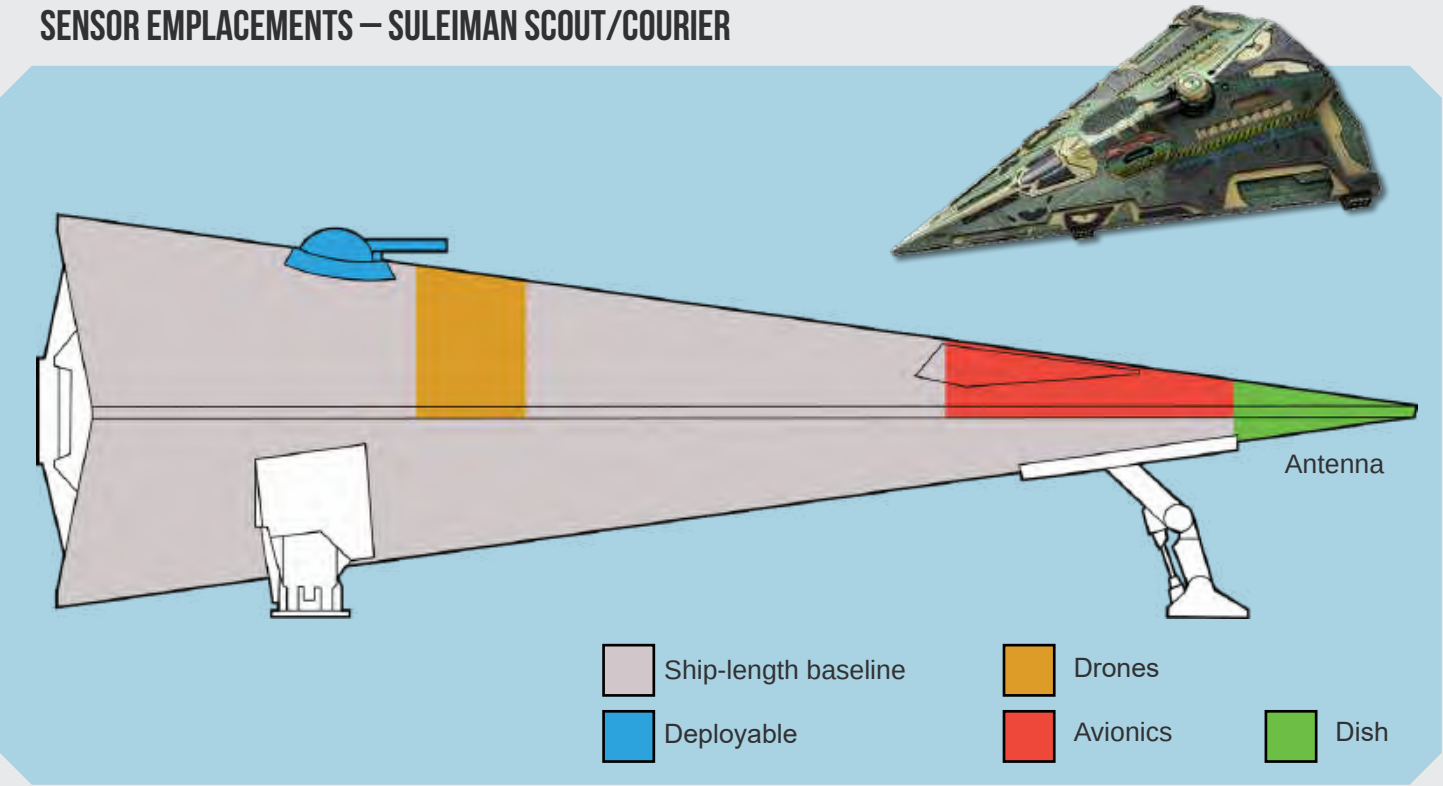
Especially on large military vessels, ships can mount huge antennae on the hull, typically in clusters. It is rare to see this on small ships, as there is not enough area to make it worthwhile. This is an option for sensors that cannot integrate with the hull.

BAY

For those sensors which are simply too big to fit into an antenna cluster but cannot be distributed over the hull, there are sensor bays, outfitted specifically for one highly tuned and powerful type of sensor.

Commonly referred to as 'observatories', bay-mounted scopes greatly increase magnification and traverse. These are the primary instruments of truly long-range observation, some capable of observing other galaxies. They can survey an entire star system minus any parts temporarily occluded by celestial bodies and are capable of seeing ships at much longer ranges than a typical ship's sensors. Nothing stops a ship with enough spare tonnage from mounting its own observatory but most see 100 tons as the minimum necessary. Many compare observatories with a ship designed around it to a military capital ship designed around its spinal mount weapon.

SENSOR EMPLACEMENTS – SULEIMAN SCOUT/COURIER



DEPLOYABLE

Specially designed turrets or barbettes may be deployable, with their own sensors for remote data gathering or remote attacking. This covers both extendible sensor booms, which make the ship a bigger target and harder to manoeuvre, as well as detachable mounts that are essentially drones whose docking points consume a hardpoint. The main difference from a generic drone is that detachable mounts usually never leave the ship's immediate vicinity, as the ship powers and controls them using short-range tightbeam. Both extendable and detachable mounts operate a short distance from the ship, so some treat them as various means to achieve the same effect.

MISSILES

Missiles, armed or otherwise, typically have at minimum rudimentary sensors for range-finding, target-finding and object avoidance. The Scout Service has specialised missiles which are all sensors and no warhead, typically one-use probes.

DRONES

Better than missiles, the drone is an ideal, reusable remote sensor platform. They can go into hazardous places and conduct sensing without exposing the crew to harm. Drones deployed over a wide area can become a planetary satellite sensor network capable of spotting targets anywhere in their system.

STARPORT AND SYSTEMWIDE SENSORS

Woe betide the naive would-be smuggler who believes that, just because their ship's sensors have limited range, starport sensors must be similarly limited. Starport sensors have two advantages over starship sensors.

First, size is no object. A starport can field the largest sensors it can afford. This typically means it will affix all sensors on antennas and dishes if it has the Credits.

Second, a host world offers the potential for very large aperture synthesis, the ability to link sensors across extreme ends of a planetary surface or orbit to form one huge virtual sensor. This provides a massive advantage in detecting, identifying and locking onto targets. As it is composed of many smaller sensors, damage to one piece of the compound unit merely degrades its capability by a small percentage, while identifying the location of a threat.

Theoretically, a set of sensors separated by long distances can increase the resolution of scans. For example, two installations set at opposite ends of a star system could, in theory, yield a resolution of one metre or better at 1,500 parsecs' distance. The data at that range would be thousands of years old but could identify alien civilisations expanding toward Charted Space.

GRAVITICS

No matter their specialisation, all engineers aboard a starship should be passingly familiar with the field of gravitics. Much like electronics, gravitics can be found in all facets of a modern interstellar spacecraft's operation, with applications ranging from propulsion to life support and sensors to lifts. The introduction of gravitics represents a paradigm shift similar to the introduction of electronics; something that might not be entirely surprising once one considers that both entail the production, manipulation and exploitation of one of the universe's fundamental forces.

Those growing up on worlds of TL9 or higher find the seemingly effortless hovering of g/cars and air/rafts a familiar sight. It is easy to forget, having become so accustomed to these machines, how miraculous they seem to sophonts from low-tech worlds. In the absence of gravitics, all means of flight are rather laborious, be it air or space. To remain aloft, aircraft require either constant forward power which their wings translate to lift, some means of flotation, or constant downward thrust.

In stark contrast, gravitics not only permit a craft to take off and land vertically but also allow the vehicle to do so without need for reaction mass. All that is required is power for the drive and nearby mass to interact with. This combination of operational flexibility, compact nature and low operational costs have caused gravitics to revolutionise space travel, dropping the cost of transporting materials to less than a thousandth of what was possible before its development.

Gravitics is widely deemed the first of the great inventions, followed by nuclear dampers and then jump drives.

Historical records from every world that independently developed rocketry prior to interstellar contact note the complexity of rocket science, which tails off after introducing gravitics. This stems from the fact that early chemical-based reaction drives are barely capable of achieving orbit around most worlds, needing a high degree of precision engineering to make such systems work. This fades from public consciousness once easier alternatives such as gravitics become available.

GRAV PLATES

The basic component of all gravitic applications is the gravitic module, a tiny device that can couple itself to nearby gravity fields and, through them, apply force against the mass generating the field. There are many variations on the mechanism, although they all exploit how gravity and energy work at extremely tiny distances, as explained by the Consolidated Theory of Gravity, or Lida Agidu Migekka in Vilani.

The most commonly encountered form of these gravitic devices is the grav plate, an arrangement of a series of grav modules as a flat or slightly curved array. A single grav module, made up of millions of nanometres-wide units, may be only several square micrometres and one square metre might have billions of these modules.

TESTING GRAV PLATES

When purchasing replacement grav plates from second-hand sources, a brief power-on test to see them hover at 1G is not sufficient. The proper way is to insist upon a power-on test for a minimum of five minutes, then touching the plate's housing with a damp rag. If it can output a consistent 1G for the entire test and does not feel warm, it is acceptable, whereas any significant warmth or wavering in output is cause for rejection.

When grav plates degrade, they tend to do so in patches; one grav module fails, causing increased resistive heating which heats neighbouring modules, causing them to degrade in turn. This makes replacement of individual grav plates far more feasible but does raise the question of what to do with failed plates. Many manufacturers offer a discount on new plates if turning in older ones at the same time. However, reuse is entirely possible. For example, there is a similarity to the failure mode of grav plates and the resistive heating used in commercial hot plates.

Grav plates affect all mass within their operational envelope, a roughly ellipsoid volume centred on the plate, dimensions varying depending on design constraints and power application.

Grav plates are, in spite of their mechanical simplicity, complex devices to manufacture. Even with the development of the Consolidated Theory of Gravity, grav modules require very precise manufacturing techniques normally developed at the end of TL8 or early TL9 to exploit the quantised nature of gravity. Arrayed and sealed into the final grav plate, they prove to be a very reliable, robust solid-state device of simple maintenance, in contrast to their difficult manufacture.

The production of grav plates is quite similar to that of microprocessors. Even the best manufacturing techniques are not perfect, especially when there are billions of components per square metre to print. When grav plates leave the factory, they are rated in a similar method to processors based on observed performance as compared to the theoretical maximum. Ones with minimal failed units and low thermal output sell at a premium, while those that generate more heat and less gravity sell at a discount.

INTERNAL GRAVITICS

The most immediately noticed application of grav plates is creating artificial gravity environments aboard spacecraft or on worlds with weak surface gravities, making long-term habitation by sophonts feasible without the inconveniences and health risks of low gravity or freefall. Conversely, they can generate a gravity field of equal strength but opposite direction to negate a world's surface gravity, creating rooms or vertical accesses where a person may move as if they were in freefall. This is great for planet-based training of spacers, to say nothing of recreational applications at theme parks and other venues. Some leverage this to actuate a lift platform with little of the infrastructure mechanical lifts require.

Gravitic physics leads to a consequence, that of lumpy gravity. Grav plates have an ellipsoid area of effect. Except for Droyne vessels, most ships are not made out of half-ellipsoid rooms, so grav plates tend to have overlapping fields. This is mitigated during ship design by using either large overlapping grav plates with uneven application of power or many low-power overlapping plates to ensure 0.9-1.1 G everywhere within a vessel. Some pleasure craft and liners go so far as to use centrally-generated gravity or one large grav plate underlying the entire floor for an even gravity field, but this tends to be expensive and difficult to repair.

An equally important use for these basic grav plates is inertial compensation; by having three sets of grav plates arranged orthogonally, it is possible to combine their pulls in any direction within their area of operation. If a vehicle equipped with such a setup is aware it will suffer an acceleration, the compensators can create an equal and opposite acceleration inside it, 'cancelling' its apparent effects for those aboard. Certain manoeuvre drives and lifters link into oversized grav plates designed to accelerate every atom of the ship and its contents equally to reduce or eliminate felt acceleration. However, the usual approach is to accelerate the hull, lifter, or drive unit rigidly connected to the hull. This brings along its contents, similar to reaction drives.

Grav plates, however, cannot change their fields arbitrarily without specialised modifications and therefore are ill suited for dealing with sudden or violent accelerations. Grav plates take a few seconds to 'warm up to speed' when turned on or changing intensity, so collisions, scrapes, weapon impacts and other such surprises are all things the inertial dampers are too ponderous to adequately deal with, whereas planned accelerations are easily handled. For this reason, grav plates are rarely set up to accommodate more acceleration than the spacecraft's manoeuvre drive can generate, though this can cause problems with craft that utilise auxiliary reaction drives for additional thrust.

LIFTERS

Beyond their basic applications in life support, the second most commonly encountered form of gravitics is the lifter. Lifters have often been called 'grav plates with their polarity reversed', which, while not technical language, is an acceptable summation of how low power, early lifters work.

It is a common misconception among many lay sophonts that gravity drives such as lifters, g-drives, and m-drives are 'inertialess' and so they violate Agaashir's Law of Reciprocal Motion or, among the Solomani, Newton's Third Law of Motion. This is incorrect; they very much do obey conservation of momentum. It is by pushing against the ground that they generate lift.

As solid-state machinery, lifters have no moving parts but there are noticeable cues that they are in operation. Lower-tech lifters make a characteristic low-volume, high-pitched, faintly perceptible whine as the individual grav modules flick on-and-off at a high frequency. An always-present sign of lifter operation is a soft but persistent breeze emanating from beneath the vehicle, akin to a downward thrust far too gentle to lift the vehicle. This effect explains the strange sensation when putting

a hand or equivalent under a lifter in operation, for as it enters the field, it suddenly feels slightly heavier, as if wearing a lightly weighted glove. That is because the hand is being pushed against, helping the lifter stay aloft.

Lifters work in concert with landing gear when performing wilderness landings on uncertain terrain. The ship slowly sets down, putting more weight on the landing gear until either the lifters shut off or the ground gives way. If this happens, the lifters reengage to keep the ship from getting stuck, which can either find another landing spot or hover in place.

There are many videos of ships using lifters to fly low to the ground, conducting wilderness deployments and recoveries of ground vehicles or low-flying grav vehicles without being on the ground. In some cases, this is done for mobility, with the pilot intending to be close to the ground for as few seconds as possible. Others do it for legality as the ship has permission to fly but suffers consequences should it touch down. Operationally these cases look very similar, except that the former more often involves either actual exchange of weapons fire or weapons moving into position to fire on the ship.

Lifters are very useful for efficient, frictionless movement close to the ground but are not the speediest mode of transportation. Similar to helicopters, their main form of attaining translational motion is by inclining the angle at which the force keeping them airborne is applied. In low-tech lifters, this is done by physically rotating the lifter plate assembly, whereas in a more sophisticated lifter's case it can be done by correctly timing the activation of the grav modules that make up the plate, using beamforming techniques to tilt the angle of the resulting gravity field relative to the surface. By doing this, basic lifter craft can achieve reasonable speeds on a standard atmosphere world. Going faster requires adding further propulsion systems, which are more concerned with forward velocity than keeping the vehicle off the ground. Most lifters, especially low-tech ones, operate in a low altitude regime of between half a metre off the ground for 'ground' vehicles and 50 metres for 'air' vehicles, but most lifters can in theory reach low orbital altitudes.

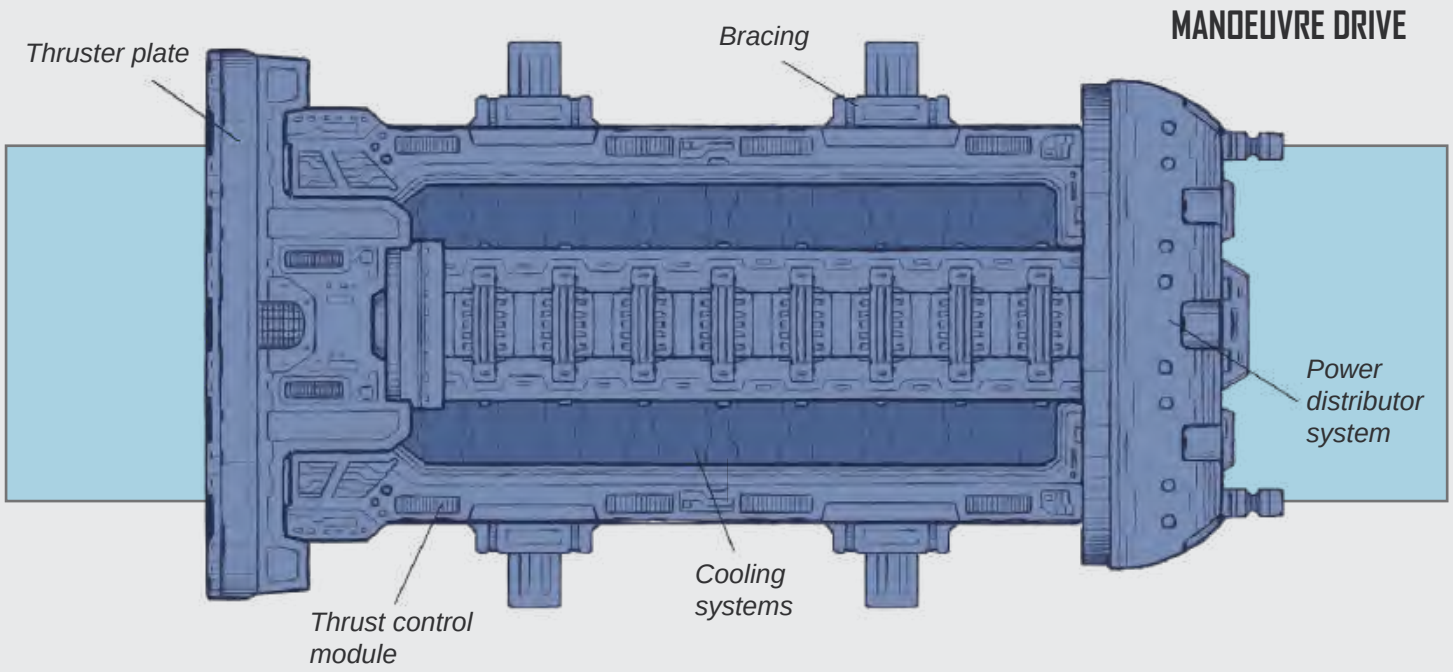
'Can' does not mean 'should'. Riding in unsealed vehicles without a vacc suit has clear dangers of rising into too thin air. Even with vacuum-rated equipment, there are other concerns. Hovering at orbital altitudes is distinct from being in orbit as the latter is more about achieving orbital speeds than pure altitude. Being almost stationary in such an environment can result in a severe admonishment from local traffic control at best or, at worst, colliding with something moving at orbital velocity and being turned into a rapidly expanding cloud of debris. Unless coordinating with local traffic control or being around a world with no enforced traffic control, most consider it 'being a traffic hazard' and penalise accordingly.

As a lifter vehicle climbs in altitude, it needs to increase its operational envelope size so that it encompasses enough mass to keep it aloft. In doing so, it increases its power expenditure; the bigger the envelope, the more power it draws to keep operational. To deal with this increased draw, the lifter can decrease the strength of its generated gravity field but that generates less lifting power for a given field size.

Larger power supplies, lifters manufactured from higher-efficiency grav modules and optimised field geometries can all increase the altitude a lifter vehicle can attain but even an idealised, perfectly efficient lifter will inevitably reach a maximum operational altitude of roughly one planetary diameter. Worlds with dense atmospheres have more available mass to push against beyond the surface, so they allow for a slightly higher operational ceiling; worlds with thin atmospheres allow slightly lower. Beyond this point, a lifter simply cannot generate enough lift to keep itself aloft.

On any modern starship designed for planetary landings, lifters are included in the hull, much like landing gear. Normally integrated into the ventral hull, they are sometimes co-located with the landing gear bays but more often spread among the ventral surface. These lifter plates provide redundancy and a degree of fine control to allow the vessel to take off and land vertically with minimal difficulty, as well as to hover at any desired altitude.

Naturally, there have been many 'creative' applications of lifters over the years. One well-known example is to use lifters to 'stick' a ship to the ground. A favourite of the Imperial Interstellar Scout Service for dealing with hurricanes and other high-speed winds, landed scout ships will often activate their lifters with a reversed polarity, attracting rather than repelling the ground. In doing so, the scout ship more firmly presses itself against the ground and it becomes harder for strong gales to blow away the ship. This even works to 'land' under an overhang when touching the ground would be hazardous. This technique depends on the exact makeup of said ground, not working well on sandy or sooty terrain and better suited for solid rock. Starships fare better landing on concrete, metal or other solid surfaces.



As with any auxiliary propulsion system, starships flying solely under lifter power are rather ponderous, most reaching top effective speeds of about 25 kilometres per hour, which is not ideal for rapid transportation but sufficient for moving around a starport. Lifters are ideal for moving things easily and cheaply but in no particular hurry from place-to-place. For longer-range travel, particularly to cross the vast distances of space, a ship needs a larger system such as manoeuvre drives.

MANOEUVRE DRIVES

At any busy starport, one can watch as ships prepare to take off and head towards the planet's jump limit. One will most likely see a vessel gently hover up a few metres into the air before it starts to accelerate onwards through the outbound flight corridor, the glow of its engines shrinking as it climbs up the atmosphere.

This scene, common to those accustomed to space travel, is only possible thanks to the manoeuvre drive, commonly abbreviated 'm-drive'. In the smallest of star systems, such as those around M type main sequence stars, planets are still many millions of kilometres from one another at best. Even with modern HEPlaR reaction drives – see page 96 – limited burn endurance makes travel via reaction drive a long and complicated affair, requiring finely plotted and executed courses to make the most of their propellant.

The advent of manoeuvre drives is the point where the prospect of true space travel turns from a tantalising dream into a practical and, more importantly, economical reality. Another product of gravitic technology, manoeuvre drives are sometimes termed 'souped-up lifters', a moniker that is only superficially correct. In truth, they are different beasts in both construction and operation.

Entering a spacecraft's engine room, the first major difference one will note between a manoeuvre drive and a lifter is its bulk. M-drives are visibly larger than a lifter of equivalent output. A manoeuvre drive has significant length, width and depth, comprising multiple thruster plates, a thrust control module, coolers for both, a power distributor system, as well as the appropriate bracing and structural elements. The first four are often arranged in an approximate cylindrical configuration and sealed inside a housing containing an inert atmosphere under normal operation, unlike lifters or grav plates.

The thruster plate consists of multiple layered grav module arrays. This allows significantly more force than lifters can exert at the cost of more power usage, generating significant amounts of waste heat which the system must remove to prevent drive degradation.

The coolers are packed conformal to the thruster plate and thrust control module. Grav modules fresh from the factory and earmarked for manoeuvre drives are almost 100% efficient devices and do not generate appreciable amounts of heat. Modules with lower efficiency frequently become lifter or grav plates. However, continual use will degrade the thruster plate, made worse by the relatively high power consumption. Thus, heavily used thruster plates run hot and risk a cascade

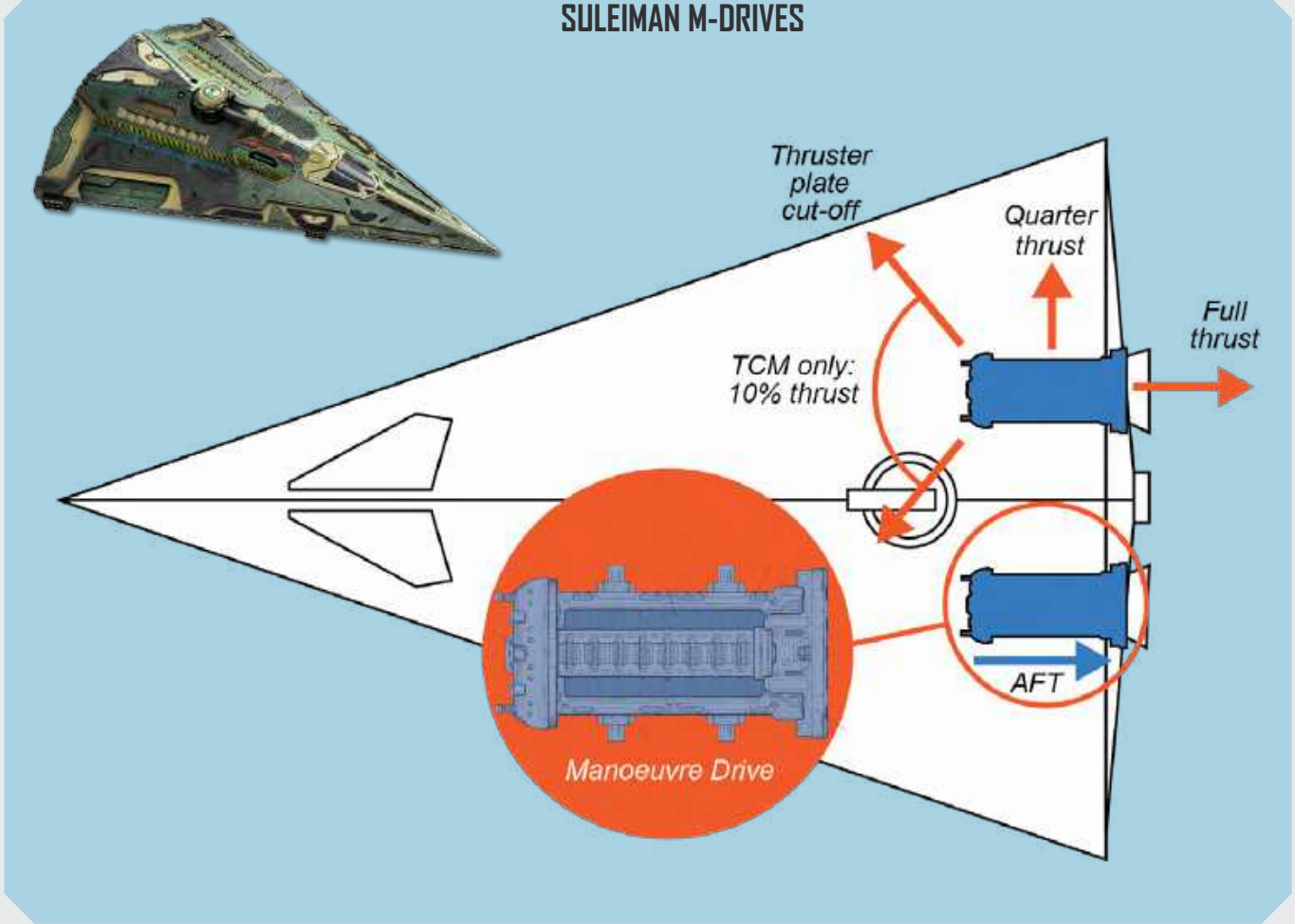
failure under high output. Active cooling minimises this degradation, extends the useful lifespan of thruster plates and prevents one plate's cascade failure from taking out other plates.

The thrust control module is a smaller set of a series of grav modules individually gimballed to allow three directions of freedom. This gimbal must transfer high variable-directional thrust loads to the ship's frame and as such is the most mechanically complex portion of m-drives, as well as the only non-solid-state component. It is usually sized to provide up to 10% of primary output alone but is intended to 'warp' the thruster plate's output, allowing the main drive to provide off-axis thrust. This combination is less efficient at roughly one minus the sine of half the angle, dropping to just over one-quarter of normal thrust at 90° and zero at 180°. When needing thrust far beyond 90°, such as reverse thrust, deactivate the thruster plate and the thrust control module's 10% provides enough thrust.

Extremely specialised craft can forego the thrust control module entirely by gimballing the thruster plate, transforming the plate into an oversized thrust control module. This allows greater manoeuvrability at the cost of additional volume taken up by the gimballing system, which will not fit inside most standard engineering spaces.

Manoeuvre drives usually mount at the aft of a ship, as ships use sideways thrust more often to adjust a ship's attitude than to laterally accelerate the ship. Even on a single drive, the thrust control module can apply thrust off-axis to apply torque to the ship. A few mount manoeuvre drives on the sides, typically for increased agility at some expense of maximum thrust. Mounting to fore rarely provides any advantages and is much more visible. Internal mounting to muffle the glow is possible but its ionisation emissions still need to be routed outside the ship, making the drive less efficient. Rarely do engineers mount the drive precisely at the centre of mass, as the ship will need a secondary thrust control module to allow paired off-axis thrust.

SULEIMAN M-DRIVES



Despite only being able to apply maximum thrust in a narrow cone directly behind it, thrust vectoring is one of the manoeuvre drive's most useful attributes, as it allows a single drive to control not only lateral translation but also the attitude of the craft. By mounting two manoeuvre drives and vectoring them independently, a ship can control its pitch, roll and yaw. If only mounting one manoeuvre drive it will allow different thrust vectors in the same plate, resulting in lower agility due to a shorter moment arm.

This thrust vectoring, being core to proper control of a spacecraft, is one of the chief duties of a spacecraft's avionics. Translating a command from the pilot in the form of a joystick tilting, a sound or a neural impulse into the direction and strength of an m-drive's thrust is far from trivial. This is complicated further by a need for balancing; although many mount m-drives so their combined thrust axis acts through the spacecraft's centre of mass, they can change this by the fullness of the cargo hold or fuel tanks and location of those on board. Accounting for this and adjusting the drives to compensate is one of the most computer-intensive processes that a ship's avionics must account for.

The directional nature of the m-drive's thrust is the reason why most starships intended for planetary landings include lifters. The drop-off in thrust when attempting vertical take-offs or landings would make it so that few civilian ships would have enough thrust to lift off the ground. Additionally, while the m-drive is always mounted along the ship's thrust axis, it is rarely mounted in the exact centre of mass, which renders many ships unable to reliably hover using the m-drive alone. Lifters are placed to facilitate hovering, liftoff and landing. In situations like these, lifters allow a starship to move off the ground without flipping over and either speed up enough to generate sufficient lift for flight or, in the case of non-streamlined designs, brute force their way into space. This is why spacecraft flip 180° when reaching the mid-point of their journeys as while they could apply thrust in any direction, the drastically reduced output makes it that reorienting the ship remains the most efficient and quickest way to complete a journey.

Thruster plates couple to any mass within range, a spherical radius proportional to the object's mass and size such that larger objects can be reacted with from longer distances. Consequently, if an object is within operational range of a thruster plate, it will be pushed against and help accelerate the plate. In star systems, the star or stars are the main objects the drive pushes against but if outside their range, the interplanetary medium can also be used, albeit with very low efficiency as the drive struggles to 'grab' onto it due to its diffuse nature. The effect is even worse with the interstellar medium – without expensive, power-hungry modifications of no use to most ships, manoeuvre drives are ineffective when far from any significant mass that would attract a useful density of particles.

M-drives produce visible ionisation effects when in operation, the colour and pattern depending on exact details of manufacture, while brightness depends on thrust used. It is possible to identify the exact model of a drive based on the spectra of its emissions, so disguising this is another reason why pirates sometimes rig lights around their drives. When ships from a wide array of manufacturers gather a rainbow of colours coming from manoeuvre drives can be seen. Shades of blue are the most common for ships made in the Third Imperium, thus the infrequently used

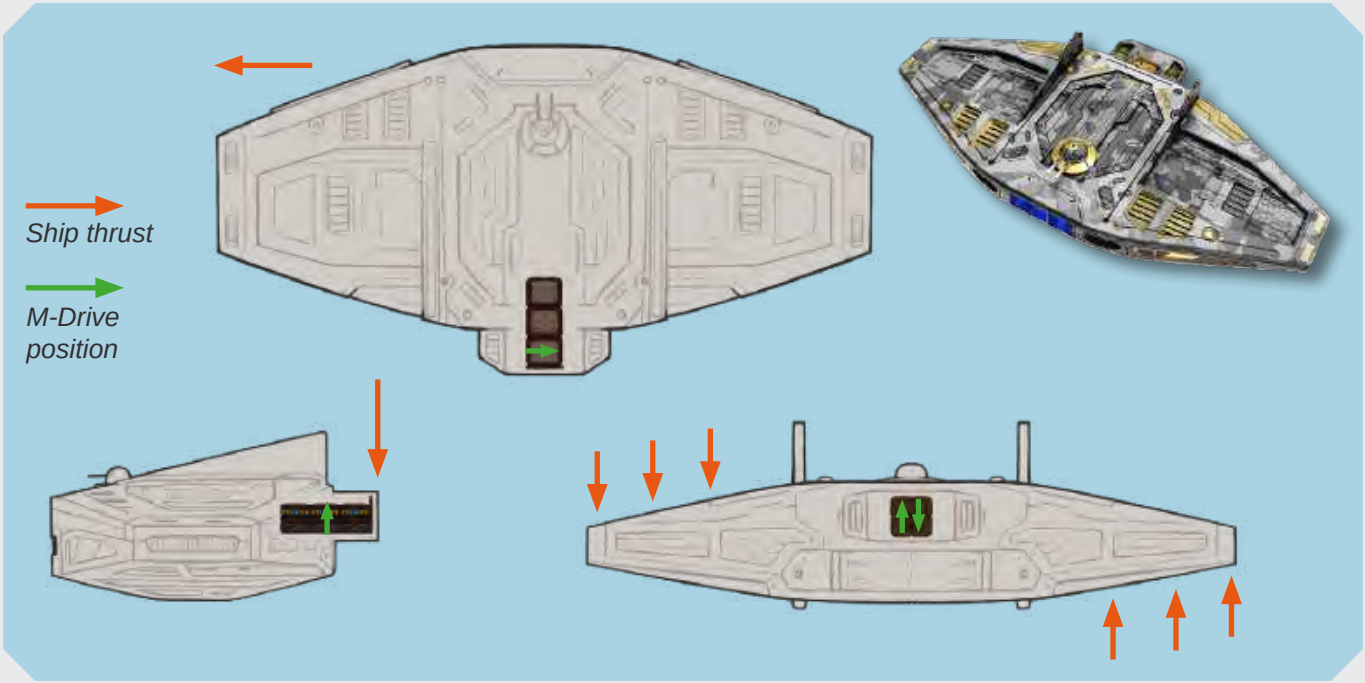
HIGH GRAVITY WORLDS

A ship can use manoeuvre drives and lifters together. This is more common when taking off from high gravity worlds.

A ship with manoeuvre drives rated to provide 1G of thrust would usually have lifters rated the same. When landing on a 1.25G world, the manoeuvre drive may angle its thrust downward, providing 25% thrust – 0.25G – which adds to the lifters' 1G to counteract the world's gravity. Lifters can be 'overcharged' for several minutes, long enough to move far enough from a planet that the manoeuvre drive alone can take over, although this risks burning lifters out if done for too long at a stretch.

Ships with drives rated for 1G can use this trick to take off from worlds up to just short of 1.5Gs, with increasingly precise angling needed to counteract higher gravities. The planetary Size code A denotes the largest worlds generally deemed habitable, with a maximum just short of 1.5 Gs. This is not a coincidence, although the long term effects of high gravity on unaccustomed sophonts is a consideration. If the ship only has 1G of thrust, avoid landing on worlds with Size code B or higher unless there is good reason to believe that ship can take back off again.

ANIMAL SAFARI SHIP - SHIP THRUSTS



GRAV VEHICLES

There exist lesser forms of manoeuvre drives, such as grav vehicle engines. As far as starship crews are concerned, these can be considered less powerful, less expensive manoeuvre drives that operate closer to gravity sources. On large ships that carry many grav vehicles and engineers, it is common for junior manoeuvre drive engineers to maintain and repair the grav vehicle engines, as they have fewer parts and less that can go wrong. Certain relatively powerful grav vehicle engines, capable for use in going from a world's surface to orbit and even its moons, are known as 'gravitic drives'.

Manoeuvre drives being far more powerful and far more expensive than grav vehicle engines, it should come as no surprise that they outperform grav vehicles. Even a basic 1G m-drive is faster than all but the fastest g/racers in Charted Space, although not necessarily more agile. Those who forget how much more expensive ships are than grav vehicles can sometimes be reminded of the difference in performance. This causes no end of nightmares for planetary defence forces using grav vehicles to intercept smugglers and is one of the chief reasons why system defence boats exist.

slang 'blue rainbow' for the backside of an Imperial Navy fleet. When a noble or planetary ruler says, 'not until I see the blue rainbow,' they are demanding the departure of whatever navy ships are present. Even within regions that rely on different material sources for their m-drives, resulting in different spectra, manufacturers may seed other elements or rig lights so their drives seem more Imperial. This is not unique to the Third Imperium, as some Vargr insist on having a different colour for each thruster plate, while some Aslan engineers see anything other than yellow as a sign of an underpowered drive.

Low-TL sophonts seeing a spacecraft for the first time often mistake this glow for the exhaust of a reaction engine. For crew who often visit low-TL worlds and interact with the locals, it may be a good idea to memorise a brief explanation of the difference they can recite every time someone asks. Given the danger from the ionisation effects' heat, these sophonts have one important detail correct – do not stand directly behind an m-drive in operation.

INTERSTELLAR MANOEUVRE DRIVES

There have been attempts to optimise and use manoeuvre drives for interstellar flight, most often for colony ships without jump drives. The chief limitation historically is fuel, which seems counterintuitive on first glance as the main point of manoeuvre drives is freedom from fuel limitations.

To have manoeuvre drives but not jump drives implies TL9, so fusion power is available but not as efficient as at later TLs. Ships are often designed with four weeks' worth of power plant fuel. TL9 means 1G thrust; even if there were no time dilation as one approaches the speed of light, it would take several months to accelerate to that velocity. Being unable to reach light speed, a ship would take a minimum of a few years to cross just one parsec.

The most common solution is to reach some small fraction of light speed then drift, either using ramscoops to glean fuel from the interstellar medium or scanning for and grabbing occasional rogue icy bodies on the way to keep life support going. To do this, the crew must reserve enough fuel to power a months-long deceleration into a passing star system to scavenge for water if not enough fuel was found or to decelerate into the destination star system. Few of these efforts reach their destination within the lifetimes of those who built the ships.

This has proved an expensive and risky approach, so a civilisation almost never attempts it once contacted by interstellar society and it gains access to jump drives; by the time the Third Imperium learns of such an effort, there are only historical records of it. Some have attempted this even with jump drives available, to traverse regions of space that starships struggle with for a lack of places to refuel a jump drive but it generally proves more viable to set up 'jump bridges', stations in interstellar space that ships can jump to and refuel at.

TRACTOR/PRESSORS

Manoeuvre drives and their cousins spread their reaction over a large volume of effect. With beamforming, gravity waves can be focused to impose significant force on an object, although there is always a maximum effective range. When used to pull an object this is a 'tractor'. When used to push an object this is a 'pressor' or 'repulsor'. Fundamentally, this is the same system, although lower TL versions are only able to act in one of the modes.

Tractor/pressors are rarely present on a ship without a specific purpose. Certain patrol and pirate ships famously use them to secure targets for boarding.

Less well known but more widely employed are rescue ships, whether in space or to pluck people out of hazardous situations on a world's surface. Some use these systems to assist with boarding and loading while at untrusted landing sites, keeping their ship far enough from the ground to make getting aboard difficult without assistance from the ship or some means of flight.

Small, short-ranged tractor beams, 'microtractors' or 'microgravitics' when speaking generally, have a range of everyday applications. Belters use small, short-range tractors to pull in ore chunks they blast loose from planetoids. High TL medikits come with a handheld unit that allows a doctor to manipulate internal organs without breaching the skin, paired with sensors that allow the doctor to see inside. At even smaller scales, some high TL cleaning tools and robots employ microtractors to sweep up dust.

Micropressors have found particular application when employed in rings or spheres to squeeze things, known as 'gravitic focusing'. This is a critical enabler of portable fusion power, being the primary way to keep plasma contained. Plasma, fusion and meson guns use this to cram their destructive payloads into narrow beams. Meson communicators do likewise, although more for power efficiency than to damage their target.

GRAVITIC SIGNALS

Just as it is possible to transmit radio at low enough power to not cause an electromagnetic pulse, gravity waves can be generated at low enough power that they cause no significant motion but instead solely transmit data. Called 'wireless gravitic connection', gradio is the more commonly used name. While any functioning grav vehicle engine, lifter plate or manoeuvre drive is capable of sending gravitational pulses, encoding signals into tiny fluctuations in these pulses or detecting them requires a higher TL.

A more widespread form of gravitic signal manipulation is gravitic lensing. A strong point source of gravity bends spacetime around it which can focus a diverging laser or radio beam into something that disperses much less, which has applications for both weapons and communications.

JUMP DRIVES

Although other means of faster-than-light travel have been theorised, mostly by speculative fiction authors and breathless scientists hoping for significant research grants, the jump drive remains the sole means by which starships can traverse the distances between stars within any reasonable length of time. From the weeklong transit to the 100-diameter limit, the jump drive and its operational principles have shaped interstellar society for millennia. As such, even crew uninvolved with the jump drive's operation should have a basic familiarity with them and their operation, including crew aboard non-starships.

THE BASICS OF JUMPSPACE

Despite differences in their construction, all jump drives are beholden to the laws of jumpspace. Even after millennia of use, scientists do not fully understand jumpspace, largely due to the difficulties of running experiments on something that renders all it touches into subatomic particles and energy. Much of the existing data on it comes from the work of the Jumpspace Institute on HRD/Vincennes and its predecessors, although other polities outside of the Third Imperium maintain their own research institutes. In spite of their efforts, models of jumpspace created using this data are incomplete – we know how it behaves but the why of it eludes us. However, from these models we can glean some basic operational principles of jumpspace and how best to avoid its wrath.

JUMPSPACE

Many believe jumpspace comprises the 'bulk' in which our universe is embedded. A common, if trite, analogy is of viewing our universe as a 2D sheet in a 3D space, with jumpspace all that is above and below it. It is unclear whether jumpspace is part of our universe, another universe, a series of universes parallel to our own, or something external to our universe altogether. This uncertainty gives rise to different nomenclatures denoting the reality in which we live, with the most common being 'realspace'. Critics regard this term as a misnomer, pointing out that jumpspace is very much as real as the space in which we live, irrespective of how alien it might be. This book uses the term because it is how most of our audience already refers to it.

COREWARD WAVE

There are a few spacer's tales of someone to coreward jumping through some sort of massive energy wave. They encountered blue sparkles in jumpspace at about the time they would have passed through the wave, with the duration roughly equal to how long it would have taken to pass through the wave, had their position in jumpspace corresponded to their realspace position. If these tales are true then there is or once was some sort of curious phenomena, potentially useful for navigation within its region, somewhere in that direction. Unfortunately for would-be researchers, this is far from the Third Imperium's borders, either deep within the Vargr Extents or entirely beyond them.

When performing a jump, ships translate from the 'surface' of realspace to a certain 'height' in jumpspace, called the jumpspace level. Studies prove jumps of different distances correlate to different levels, with the longer the jump in realspace the deeper a depth travelled through jumpspace. No other correlation is found between realspace and jumpspace, and studies suggest that scientists will not ascertain any. When jumping, a ship is removed altogether from realspace, such that the concepts of its 'position' and 'speed' are meaningless for the duration, until reemergence. It is possible that the ship might have position and speed within jumpspace but these do not map to realspace equivalents and there are no perceptible external reference points within jumpspace, making determination of location and velocity impossible.

MISJUMPS

Throughout Charted Space, many thousands of jumps take place every day without incident. Despite the concerns of a few paranoid souls who find the strange nature of jumpspace abhorrent and refuse to step aboard a ship that ventured into jumpspace, let

alone enter themselves, the jump drive has proven a reliable technology in use for over ten millennia. It is entirely possible to live, work and die aboard a starship without ever encountering unexpected behaviour. However, there are always exceptions. Called misjumps, these are a constant risk for starship crews, one that any captain wishing to keep their ship and crew intact will make great efforts to avoid. These efforts are mostly successful; the vast majority of misjumps are due to faulty equipment, unrefined fuel, early jumps or operator error.

Nonetheless, it is occasionally possible for even the best-maintained ship with the finest crew to suffer from the capricious whims of jumpspace. A crew's helplessness makes misjumps worse, as when one strikes there is little recourse but to glare at the astrogator and hope for a safe emergence.

TIME CONSTANT

All these properties stem from perhaps the strangest characteristic of jumpspace: Constant time. In realspace, the speed of light 'c' is a constant that governs all motion. As one approaches c, it becomes increasingly harder to accelerate further. In jumpspace, time governs motion, not speed. In stark contrast to the speed of light, the more one diverges from this time constant the harder it becomes to diverge further. As speed equals distance over time, by making time constant and unbinding speed, both it and distance can be freely varied under the relationship 'distance over speed equals time', allowing arbitrarily high speeds far beyond c in order to satisfy it.

SPEED = DISTANCE/TIME

TIME = DISTANCE/SPEED

This rather strange property of a 'time constant' makes jumpspace utterly hostile to matter. The physics we know cannot take place under the rules of this foreign space. In order to survive it, jumping ships detach a small pocket of realspace, bringing it with them as they enter jumpspace, as a jump field. Beyond protecting the starship from nonexistence, the jump field establishes the relationship between time in jumpspace and realspace. While we cannot measure the passage of time in jumpspace, if such a concept is even meaningful, the 'time constant' as observed from within the jump field is ascertained to be approximately 168 hours.

While purposefully minimising the time in jump might seem like an appealing idea, deviations from the ideal time not only show a correlation to scatter from the desired realspace target point but are directly related to the odds of misjump and thus to be avoided. This is not to say it cannot be done, just not recommended. Keeping it to one week helps avoid misjumps, which when not simply disastrous are far more time-consuming than the hours this technique can save.

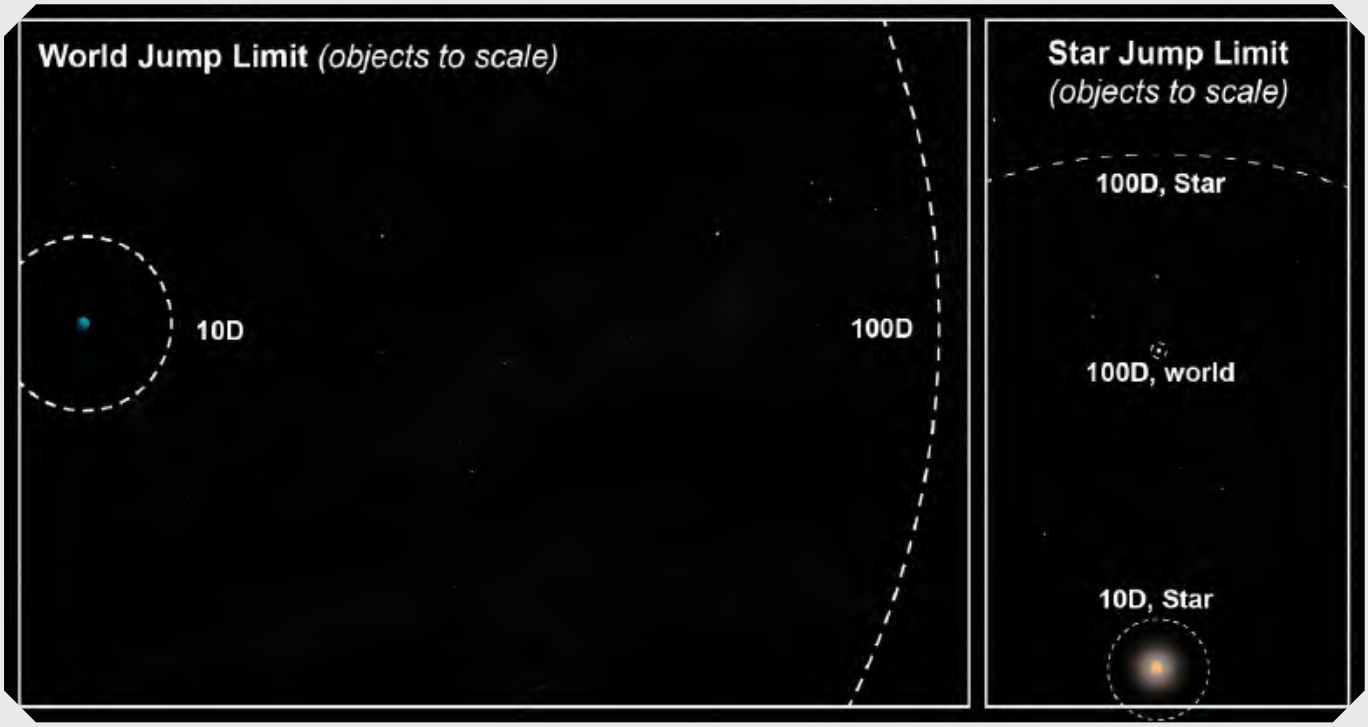
JUMP DRIVE OPERATION

In spite of the jump drive's ubiquity, the exact principles and rules that jumpspace operates under remain poorly understood. Although there are countless theories, all most crew need to know is what the jump drive does, not why or how. The complexities of astrogation and fine details of the structure of the jump drive one can find in detail in other literature, although this book attempts to cover the broad strokes.

As any astrogator will tell you, no two jumps are the same. The crew should remove from duty any astrogator who tries to repeat the exact same process for a new jump as a previous jump, believing that because it worked once it will work again. Nonetheless, any given jump can be broken down into five broad steps:

- **TRANSIT –** The journey to the 100-diameter limit, allowing a safe jump entry.
- **PLOTTING –** The planning and creation of a viable jump plot to take a starship from origin to destination.
- **INITIATION –** Jump field creation and entry into jumpspace.
- **TRAVEL –** The time spent within jumpspace on the way to the destination.
- **EMERGENCE –** Exit from jumpspace.

In an environment with as many unknowns as jumpspace, it should come as no surprise that there is no end of superstition and tradition associated with starships. Many Vilani practice jump dimming to maximise the available power even on ships with ample power, making jump dimming technically unnecessary. The Aslan will often light a candle in the ship's shrine or knock on a viewport before jump initiation, symbolic versions of announcing their entrance. The Droyne place gold coyns below the bolts that hold a jump drive to the floor, whereas traditionalist Vargr beat the first crew member to come aboard. Some Solomani believe any ship that has not had a bottle of Terran champagne broken across the hull to be bad luck and so on. There may be as many traditions as there are starships in existence. While these do not appear to affect operation of the jump drive itself, a starship's crew can see requests to skip them as an indiscretion at best, actively tempting fate at worst. As always with culturally sensitive topics, get to know the crew well enough to judge their probable reaction before making this suggestion.



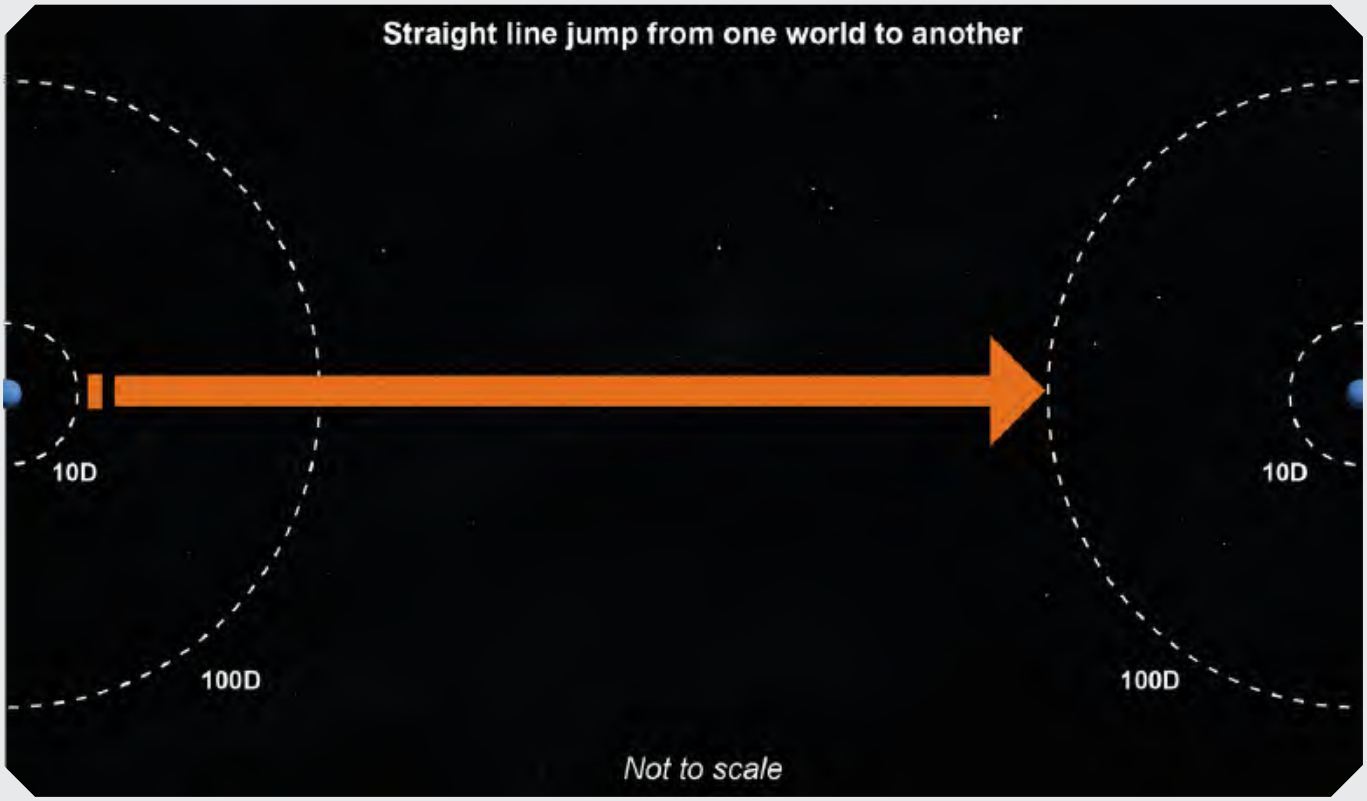
TRANSIT TO THE 100D LIMIT

Jump drives are incredibly sensitive to local gravity fields and the rate of misjumps skyrockets when near astronomical bodies or even other ships. As a result, common practice found the 100D limit, which is a star's or planet's diameter multiplied by 100. This creates a sphere known as the 'jump limit'. Many students new to jump theory assume it should be the mass that matters, such that a denser planet should have a larger jump limit than a less dense planet of the same volume. While this is somewhat the case, volume is the primary determinant for cases that most starships encounter. A jump could be attempted within the 100D limit but the risk of misjump goes up, to the point that anything less than the 10D limit from a gravity source is almost impossible. Few starship crews have done so and lived to tell the tale, none without a catastrophic misjump. Exiting a jump within the 100D limit is impossible, a forbidden zone sometimes called a 'jump shadow' and practically unreachable without in-system travel.

The first physical stage of jumping requires the ship to move past the 100D limit to minimise chances of misjumping. The 100D limit of some stars stretch beyond the 100D limit of their mainworld, forcing ships leaving that world to travel longer for a safe jump. In particularly crowded systems, a crew may also need to consider the 100D limit of local ships. For example, a 500,000 ton *Tigress* is roughly 250 metres in diameter, giving it a 100D limit of 25 kilometres. A *Suleiman* within this limit would risk a misjump, although its own much smaller 100D limit – about four kilometres – would not impact the *Tigress* in the same way as only jump shadows of larger objects interfere with jump entry or exit, fortunately for astrogators. If an object has a non-spherical shape, as with most starships, its 'diameter' for this purpose is taken as the object's longest dimension, mostly out of caution.

Anxious or rushed captains may ask to jump before the 100D limit, believing the risk of misjump to be negligible to leaving the world in a hurry. Inform the astrogator immediately of any necessary changes to the course and jump of the ship. Otherwise, spending a bit more time in transit to the 100D limit is the best option to make sure the crew's particles are not scattered throughout jumpspace.

An important fact about jump limits and anti-jump weaponry is that they only prevent safe jumps, not jumps in general. A target ship can choose to override warnings and engage its jump drive in a planetside docking bay, low orbit or within a jump damper field and will vanish as normal. The chances of this misjump being survivable are almost zero. Even if it is, scatter will likely throw the victim into an empty parsec. If facing what they believe is certain death or a fate worse than death, some captains and crews will choose this as it beats the alternative and death by jump-field-induced disintegration is generally believed to be swift and painless. This encourages pirates to be less violent



in attacks to avoid getting a reputation as savage bloodthirsty killers; pirates are not paid for cargo they do not take. Slavers have it harder.

To prevent a ship from jumping for whatever reason, the only ways to do so are to drain the fuel, disable the power, or punch a hole through the jump drive. The most common way to do such is through insertion of a saboteur at port. Other methods are faked maintenance crews for ships that do portside maintenance, and weapons fire, although the latter risks destroying the ship. At most ports any ship powering up their jump drive is assumed to be attempting to self-destruct, with the safest response being to evacuate the immediate area.

PLOTTING

A starship's astrogator has the unenviable task of planning and calculating jumps, which is oftentimes the last of their calculations during transit to the 100D limit. It is their job to analyse the ship's intended destination, the relative position and movements of relevant celestial bodies, and the pilot's course to the 100D limit before deciding on the best trajectory. The astrogator will take these factors into account and use both local charts of the origin system and remote charts of the destination to verify that the projected course will not cross any 100D limits save for the destination world or star. They may take a few hours crunching numbers with the ship's computer, before taking hours more to validate those numbers, then a moment to give these numbers to the engineer to operate the drive. They are responsible for confirming location upon jump exit, which will be the next time they have solid data to work with; while in jump, a ship is completely cut off from the universe and thus unable to sense and communicate.

The basic principles behind plotting a jump are relatively straightforward. In theory, anyone could do them with enough computer aid to perform the required calculations. In practice, most starship crews will tacitly agree that astrogation is more art than science.

Plotting a course to a neighbouring star system with nothing in between seems simple; one only needs to plot the start and end point, as there are no other gravity wells in the way. Unfortunately, there is always the potential for a rogue object. More powerful jump drives might enable routes that pass near or through other star systems. Even if a star system is present on a map, it represents a small amount of material with a lot of space all around, usually easily avoided by the astrogator. Sometimes, however, an astrogator has to plan a jump through an actual intervening star system. This requires manipulation of the jump field to arc the jump around the intervening gravity wells. Standard Jump Control software packages automatically calculate this arc, taking predictive data starting from the last known coordinates of any worlds in the destination system and projecting their trajectories to a safe emergence.

Part of the finesse of an astrogator's job is compensating for these unknown or semi-known variables, as explorers did not always finely map interstellar space and most rogue planets, planetoids and comets are almost undetectable. Charts will show reported navigational hazards as well as data gathered from long-range telescopic observation from ports but any jumping ship risks arriving at an uncharted mass without a skilful astrogator. Machines are not good at this part, although chance favours them occasionally.

ASTROGATION

In theory, jumps happen in straight lines with no arcs. Astrogation is simply a matter of calculating a straight-line shot at a distance of parsecs.

If only things were so easy.

On rare occasions, they can be this simple but usually there is some rogue body in the way, sometimes entire solar systems. Jump into them and you wind up stopping at their 100D limit instead of the destination's. Detour around them, and the ship is off course. The solution is to deviate a tiny fraction of a degree, hitting perhaps 100.01D but no closer to take advantage of spacetime's slight bend, magnified by jumpspace, in the presence of strong gravity fields. Unbend spacetime and the line of travel is 'straight' but is rarely how observers in realspace apply that term. This manoeuvre relies on near-perfect knowledge of every rogue body enroute to a destination, knowledge that – thanks to lightspeed limitations – is virtually impossible to acquire. Projecting these objects forward in time can result in some approximation but requires complex n-body simulation to achieve anything close to an accurate result. These skillsets translate well to in-system navigation as well; SDBs may carry astrogators to plan an interception course.

All told, a successful jump plot can require keen knowledge of technical software, a working knowledge of astrophysics, a willingness to take in uncountable variables and to utilise an intuition honed over years. This is why astrogation takes training.

The greater amount of potentially interfering objects along with the need for a much finer degree of control over the drive's jump field account for the increasingly higher bandwidth consumption of Jump Control software as jump distance increases.

While uncommon, it is possible for an astrogator to end up in a situation where there is no valid, safe jump solution from a specified origin. The solution to this is simple and only slightly annoying: let the captain know and ask for a new origin point without the complicating factors before reaching the unusable origin point.

While the computer handles that, the astrogator must determine the best place to finish the jump based on other criteria such as pirate prevalence and the time spent in transit. All of this decision-making, as well as the technical expertise and skill required are what justify an astrogator's comparatively high salary. Unless filling multiple roles aboard a vessel, astrogators 'only work once every week and loiter around the rest of the time' according to some jealous crewmates. However, they are the first person fingers point at whenever arrival in a new system goes awry, whether due to misjumps or pirates, to the point that the reminder of the potential consequences of a mistake can offer yet another complicating factor when calculating a jump. While for most the week in jump is often a time to take a breather and relax, most astrogators will admit that they can never feel quite at ease while still in jumpspace, counting down the hours until breakthrough.

Although astrogation normally involves plotting a course that ends 100-diameters from a star or planet, this is a much larger target than some arbitrary point in deep space. This is what an astrogator must target when jumping to an 'empty' region of space. This is the primary reason why there is well-preserved documentation of how to jump to deep space calibration points, from the early days of interstellar travel on Terra when it was the only option. Jumping to specific destinations under such conditions requires extremely precise coordinates, generally obtained from the group that maintains whatever is at the point or, especially when the destination's owners are hostile, from an observatory ship one parsec away – roughly 3.26 light years. Even with coordinates, astrogating to such a smaller target is naturally more difficult.

Ships without trained astrogators can use 'jump tapes', pre-plotted astrogation solutions that will fly a specific ship from one system to another, good for only a limited time, typically a week or less from manufacture. After that time, conditions in and

between the systems may have changed enough that the ship needs a new solution. One downside of relying on jump tapes is that the ship can only jump to destinations that have jump tapes available.

JUMP INITIATION

When all the plotting is finished and the ship is at the calculated departure location for the specific jump plot, the next step is to initiate the jump, usually by pressing a button. Once pressed, a series of events must occur to propel the ship into jumpspace so it can travel to its destination. This starts by activating the drive/shunt subsystem, including the jump drive emitters installed over the entire hull of the ship. The power plant then pushes a great amount of power through the lanthanum and grav modules in those emitters.

Once the power is flowing through the drive/shunt system, hydrogen is pumped by the jump field subsystem on the hull of the ship, expanding it out to a large bubble if employing a bubble-configuration drive, or a conformal jump field if using a jump grid – see Jump Field, starting on page 90. The majority of fuel designated for a jump is used during this process to create the jump bubble. Many compare this to children blowing bubbles from soapy water, making the external view of jump initiation fascinating to watch. The crew can only observe the bubble forming from the limited view inside the ship.

The jump will not start until the jump field is completely formed. Outside observers will only see the field engulf the ship then seemingly pop, making the ship and everything else inside the field disappear, like the universe's largest stage magic trick. From the crew's point of view, once the field fully forms and blocks out the outside universe, the ship is in jumpspace until the field dissolves at the end of the jump.

Creation and inflation of the jump field is an extremely rapid process, happening faster than any sophont can react to. Only computers have a chance of performing all the steps in time. As such, jump entry is impossible without Jump Control software, which performs safety checks such as making sure there is enough fuel before attempting to begin. Without disabling these checks, attempting to jump without enough fuel causes the computer to display an error message.

Bypassing these checks never saves significant time but does increase the consequences if one happens to have less than enough fuel upon trying to jump. A ship that began the jump process with insufficient fuel would find that part of its hull suffered misjump since the setup could not complete and eventually returned to realspace as particles and radiation, while the rest remained behind. The less fuel that is provided, the less of the ship would enter jumpspace, to a minimum of the outer skin where the jump emitters are. Some claim from a certain point of view that disabling the safety checks allows for jumping with less fuel than is otherwise needed but surviving such a jump would be nearly impossible.

A rare variant on the process is the use of 'drop tanks', externally mounted tanks that rapidly inject hydrogen fuel into the jump bubble and then ejected so their tonnage need not be brought along. This ejection often involves their partial or total destruction, as they operate in close proximity to an expanding jump bubble, making them uneconomical for commercial ships. Those who plan to use drop tanks should check with the system they are jumping from to see if the local area allows discarding them and if there are any conditions such as using jump points designated for drop tank use, especially if there are plans to return.

In addition to protecting the starship during its weeklong jump, the jump field serves the crucial purpose of determining the ship's destination. As the jump drive activates, transitioning the ship into jumpspace, fluctuations induced in the jump field as it forms make it possible to give a ship the 'push' in jumpspace towards its intended destination.

JUMPSPACE TRAVEL

Due to the temporal constant of jumpspace, the average time of a jump is approximately 168 hours. It is possible to bracket the ideal jump time more precisely via careful astrogation and precise jump drive operation. A skilled astrogator can select jump vectors that minimise the energy of the tumble setting up the ship's course, which in turn ensures it deviates less. Similarly, a well-calibrated jump drive can energise its drive/shunt and jump field systems in greater accordance to the astrogator's plot, with fewer random fluctuations. A well-trained starship crew is therefore capable of greatly reducing not only the chance of misjumps but variations in transit time and exit point scatter of jumps.

The ongoing mental welfare of the crew is of concern during these week-long jumps. Preparing the crew to sit through a jump is vital, as a whole week with little to nothing to do can create problems. Studies suggest that smaller crews find it harder, on average, to handle this boredom. Many captains create work schedules with detailed tasks to keep the crew busy and active during the trip. Maintenance on the ship's systems, particularly the manoeuvre drive and sensors, is a common choice as they will not see use during jump travel.

One constant is that destruction waits for anything that exits and travels too far from the ship. Instead of the starry black sky of space, jumpspace presents an alien reality only kept at bay by the jump field. Any matter that touches the field is eventually returned to realspace as subatomic particles and radiation. There are no records from sensors that have survived this process, so no one knows what happens between touching the jump field and return to realspace, although it is generally believed the destruction is instantaneous. This means that getting into a vacc suit and strolling outside, inconvenient as it may be on a spacecraft, is even less of an option while in jumpspace.

It is a popular rumour that staring into jumpspace causes insanity. It is a known and measured fact, so far as these things can be measured, that jumpspace looks different to different observers at different times but looks the same to a group of observers looking out from the same jump bubble at the same time, as if its appearance was a form of consensus reality. Many theorise that the majority of non-invented cases of jumpspace-induced insanity actually consist of loneliness-induced insanity – the affected person had nothing better to do than to stare into jumpspace, typically alone, due to other factors that stressed the psyche. The IISS claims that loneliness, not jumpspace, is the true cause of most mental health effects in x-boat pilots, some of whom can be alone for months at a time, although the recommendation is for any given pilot to perform no more than four jumps without relief, preferably no more than one pair of jumps. This is why the manufacturers of certain small ship classes recommend a minimum of three crew roles, thus requiring a minimum of two people, despite a lone pilot/astrogator being able to operate the ship.

Nonetheless, a good rule of thumb is to stay inside the ship while in jump. There are many reports of crew believing they could quickly fix something outside in mid-jump, only to cease work and stare off into the strangeness of jumpspace, before letting go and drifting away from the hull. Once the crew passes through the jump field's edge, they are swallowed completely, never to be heard from again in jumpspace or realspace. It is highly recommended that crew do external repairs in regular space, at a dock if possible, instead of jumpspace.

Fast drug, which makes perceived time go by 60 times faster, is sometimes used for jump travel. A standard 168 hours = 168 minutes dose makes a typical jump go by in just under three hours. More experienced spacers prefer to take a smaller dose, either to be fully awake and alert in time for jump breakout or to prevent still being under fast drug's influence at breakout, in case of an early jump exit.

JUMP EMERGENCE

An astrogator can aim the jump to influence where the ship comes out but only to places where jumpspace can put the ship. Many an astrogator compares the process to helping aim a baby as it learns to walk.

JUMPSPACE JETSAM

'Never throw anything into the jump field, as that may result in destruction of the ship' is a lesson taught to engineering students early in their education, although what actually happens is rarely this dire. Accidentally or on purpose, this does occasionally occur during a jump. In general, one of three things may happen.

Two of these are benign. The luckiest outcome is if the jetsam simply floats around in the jump bubble and returns to realspace with the ship, where the expanding cloud of hydrogen simply carries it off. Slightly worse is if the material freezes to the hull, requiring the crew to go out and remove it. Having a month's worth of raw sewage frozen to the hull rarely inspires confidence in the crew but is ultimately survivable.

Potential disaster results if the jetsam touches the edge of the jump bubble, whereupon it disintegrates and the release of energy causes the jump bubble to alter shape or ripple. The jump field subsystem is designed to compensate to some degree but in rare instances these effects are large enough to impact the hull of the ship, especially so with jump grids. This can cause a cascade of failures ending in field collapse, ripping apart every atom of the ship and everything within.

Even so, when there are things that absolutely must be destroyed, throwing them into a jump field is the most complete method of destruction commonly available to ship crews. If employing this method, break the garbage into the smallest practical pieces and throw them one at a time into the jump field, waiting for any ripples to subside before throwing the next piece.

Starting about one hour before the ship exits jumpspace, the jump field begins to exhibit some well-defined changes, most notably 'jump rumblings' which are vibrations that anyone on the ship can feel. Only those who are asleep or floating in a zero gravity area may not notice them. Most engineers, navigators and ships' sensops train to identify these changes and crews will take advantage of this warning to try to have a full complement awake and at stations when the ship emerges.

Two things happen upon emergence from jumpspace. There is a detectable pulse of gravity as the ship suddenly appears in realspace. Any remaining ionised hydrogen in the jump field generates an electromagnetic pulse or 'jump flash' which is detectable at a similar range to the gravity pulse before the hydrogen begins to disperse. If any impact with the jump field consumed a significant quantity of matter, it will usually return to realspace at this time and may contribute to the exiting jump flash. The remains of the matter consumed during initial inflation are generally left at the point of jump entry, contributing to that entry flash instead.

The ship emerges at minimum 100-diameters from any large mass but retains the realspace vector it had when it entered the jump. The astrogator's job is to compare the velocity that the destination will have upon arrival relative to what the ship has upon jump, to ensure the ship emerges into the target system with a safe and sane vector. Many believe astrogators compute in seven dimensions; three of position, three of velocity and one of time. When this is not possible, it may be the job of the pilot to do some quick manoeuvring to avoid collisions, although emerging in close proximity to another object is unlikely save around the busiest of worlds.

Misjumps often result in higher, lower, or patterned concentrations of hydrogen, resulting in detectable differences in the electromagnetic pulse. Because of this pattern, the Third Imperium has a small bounty for logs of misjumps as they help achieve higher performing jump drive creation. This bounty encourages starports to render emergency aid to misjumped ships, as they receive a percentage of it. Unfortunately, the regulations are complex enough, on top of the inherently unpredictable nature of misjumps and what can be usefully logged from them, that the bounty is essentially random when it is paid at all, although it is rarely enough to make up for the danger of a misjump. In particular, if the logs suggest the misjump was due to a preventable and well-studied error such as poorly maintained drives, using unrefined fuel or jumping inside the 100D limit, this reduces the bounty. The crew must survive the misjump to be paid, which is the biggest deterrent to those who would deliberately misjump seeking this bounty.

IN-SYSTEM JUMPS

It may come as a surprise to those who have never lived in a system with multiple populated worlds that jump drives are commonly used for in-system transit. For any two points in the same system that would otherwise take many days to travel, a 'microjump' can reduce transit time to one week. Unless one counts the outer limits of Oort clouds, solar systems are tiny fractions of a parsec in diameter. Despite this small distance, in most respects an in-system jump acts like a one-parsec jump. It is also a common way of testing new models of jump drive.

A relatively obscure but potentially life-saving trick of the astrogation trade is the so-called 'null jump'. In an emergency, such as in the middle of a pitched battle, it is possible to initiate a jump without any inputted astrogation solution. No 'push' is given to the jump field, so the ship's path collapses into a point. The jump drive consumes fuel equivalent to a one-parsec jump. About one week later, the ship breaks out into realspace where it left. This point is where the ship's vector would have carried it for the jump's duration, unaffected by gravity.

Stars and star systems are always in motion. A week of such motion would displace the ship from its starting point by hundreds of millions of kilometres, requiring a lengthy transit back to the mainworld or other refuelling point. There is the possibility of ending up more than 1,000 diameters from the star's gravity well, leaving the m-drive nonfunctional. Jump Control software can predict the distance and direction of this displacement and help an astrogator plot a jump path that compensates for it but sometimes there may be no time to run these calculations before triggering a null jump.

This technique can shake off would-be pursuers by making them believe the ship jumped to another system but there is a risk. If potential assailants are still in the area upon jump exit, the hapless ship will have jumped right back into danger, likely without enough fuel to attempt a second jump to safety.

JUMP DRIVE SYSTEMS

Every jump drive comprises four basic subsystems, although they may take different forms; the power conditioner, the control subsystem, the drive/shunt subsystem and the jump bubble subsystem.

The most prominent feature of the jump drive is the thick conduit running from the ship's power plant. The cables inside it connect directly to the power conditioner, the subsystem responsible for interfacing the jump drive with the ship's power plant. It takes in the power used to warm up the drive for a jump and, more crucially, handles and directs the astonishing power surge of the overclocked power plant. To survive such enormous energies delivered in a short time, many jump drives employ a bank of zuchai crystal energy sinks tuned and balanced for the ship. This seeps in excess energy and releases it as required. While other energy sink designs are employed in lower Tech Level jump drives, a majority of designs favour zuchai-based arrays for their compact size and efficient, reliable charge/discharge cycles.

The control subsystem closely observes the workings of the power conditioner, which monitors the status of the zuchai energy sinks. While able to store tremendous charge, zuchai crystals can be saturated, leading to their violent decomposition. It is the control subsystem's job to dynamically allocate the incoming energy to prevent sink saturation and distribute the proper power flow to the field and drive/shunt subsystems. The control subsystem runs thorough diagnostics before and after a jump as imperfections in the crystalline lattices of zuchai energy sinks can cause stresses during charge/discharge and can lead to the catastrophic destruction of the drive.

Beyond administering the power conditioner, the control subsystem contains the drive's jump governor, which allows it to operate below its maximum factor. Without it, a jump-4 drive would only be capable of jumping four parsecs, no lower. Without a jump governor, an astrogator can still attempt shorter jumps by aiming the jump line to intersect the destination's 100D limit but this is more difficult. The danger is slipping right past the target to whatever spot lies at the maximum distance in that direction, which is rarely conveniently close to a source of fuel with which to make another jump. Despite its importance, the jump governor is merely a subset of the control subsystem and not a separate component, especially as a jump drive can work without it.

By using modified high-intensity gravitic modules to 'bend' local spacetime in the appropriate ways, the drive/shunt subsystem 'pinches' volumes of spacetime and, once the jump bubble subsystem enlarges and manipulates the volumes into a single one that encompass the entire starship, sends it through jumpspace. This energy-intensive process is the culprit of the significant power needs of jump.

JUMP FIELD

Jump fields are only possible due to the special properties of lanthanides, in particular lanthanum itself. The atomic structure of lanthanides repels jumpspace, making it able to generate a tiny 'bubble' of realspace, a property not shared by most other stable elements, although barium has sometimes been used to lesser effect. Certain heavier elements have also been reported to display this property, but these are isotopes with extremely short half-lives, synthesised during jump to last long enough to be tested, making them impractical for use in starship construction.

Expanding this bubble to a useful size requires that a large amount of electricity be driven through the lanthanide in conjunction with an internal pressure, provided by injecting a gas to blow it up to size, up to a maximum diameter determined by the enclosed object's volume. This is not trivial, as interactions between matter and field can cause ripples that catastrophically destabilise it – see Jumpspace Jetsam on page 88.

Hydrogen is used to avoid these instabilities. Its atomic structure, the closest possible to a point-mass, allows for clean and homogenous interactions with the field, keeping chaotic ripples to a minimum; other elements with heavier masses and larger nuclei cause too many and too strong instabilities, an effect only made worse by using molecules instead. Hence the importance of using properly refined fuel: keeping contaminants to a minimum ensures stable field formation.

When a starship initiates a jump a series of jump emitters, part of the drive/shunt subsystem, undergo this process. The lanthanum in the drive/shunt is energised, creating a realspace pocket which is then inflated by the field subsystem through the injection of hydrogen. The emitters' gravitic modules distort local space as specified by the astrogation plot, inducing a so-called 'tumble' that will steer the ship towards its destination as it enters jumpspace. Most compare the process to simultaneously conducting thousands or millions of orchestras that have to seamlessly merge upon reaching a specific note.

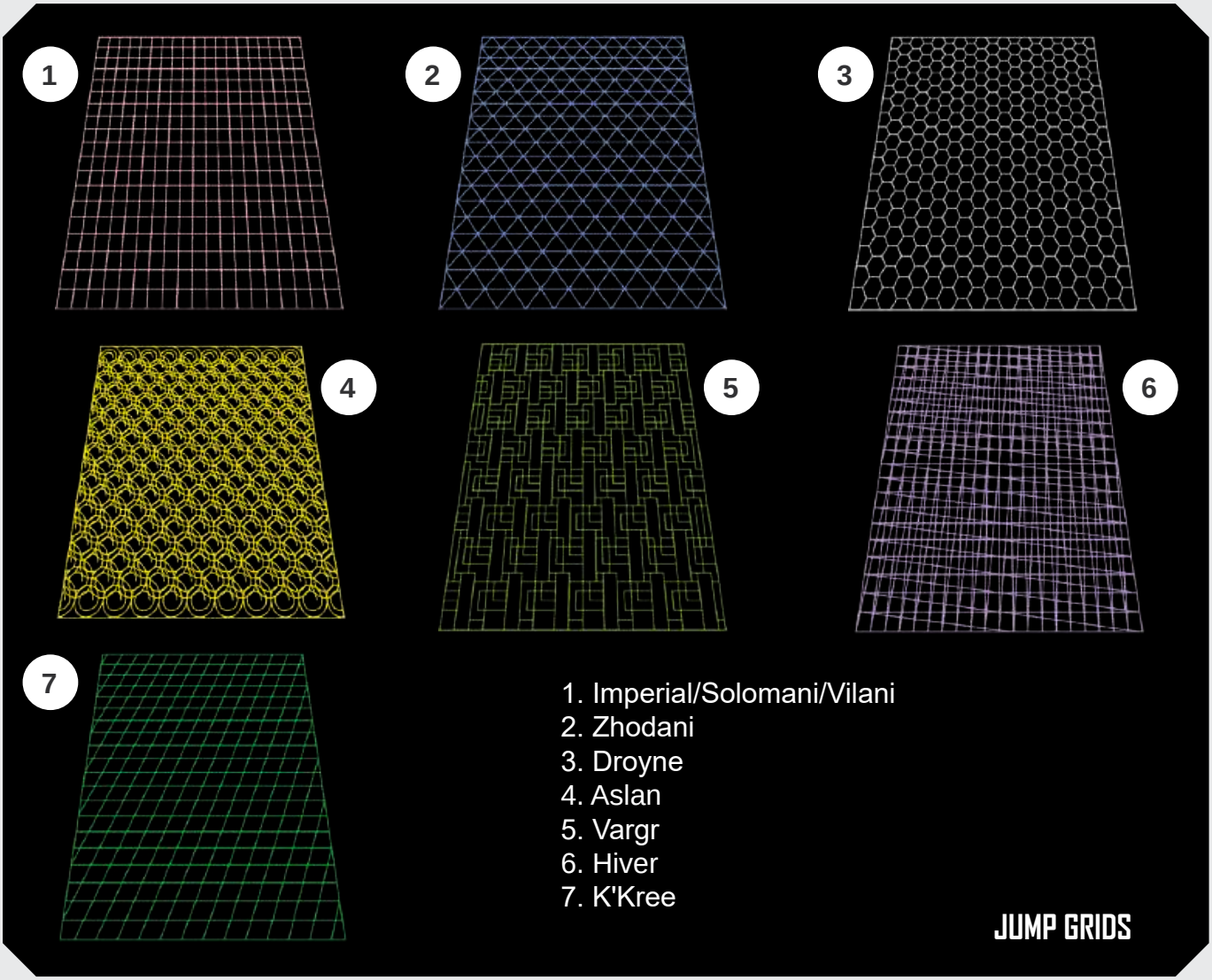
About 90% of a jump's fuel is consumed during jump entry, primarily to create the jump field, with the remainder used to maintain it during jump travel. If a ship runs out of power mid-jump or the jump field system is otherwise rendered inoperative, the ship will not be immediately endangered, but the longer this situation lasts, the higher the risk of jump intrusions – see page 92 – or outright jump bubble collapse.

The amount of fuel required for a jump is roughly 10% of the ship's volume per parsec travelled; more advanced drives can slightly decrease this. This is largely due to jumpspace's increased resistance at deeper levels, akin to the pressure experienced by submersible vehicles as they increase in depth, such that the jump bubble must maintain a greater degree of counterpressure.

There are two different paradigms when constructing emitters for the formation of jump fields: jump bubbles and jump grids. By concentrating all the lanthanum within the jump drive, a jump bubble creates a spherical field around the ship centred on the jump drive. This allows a ship to vary its effective tonnage from mission to mission, making drop tanks and external cargo possible, but risks enclosing unaccounted nearby debris which could result in a misjump.

The other configuration is the jump grid, a regular mesh of lanthanum conduits embedded in the outer hull layer, which disperses the protective effect by creating many smaller bubbles along it which merge together, bringing the field closer to the hull the less concentrated the lanthanum is. Their distributed nature permits finer control of the forming jump field, allowing the drive to better compensate for external influences and permitting a ship to safely jump closer to a gravity source. A side effect is that the smaller surface area of the jump field must disperse the same amount of energy as the bigger bubble, making jump flashes brighter and easier to detect.

Whatever the configuration, it is possible to identify the species that manufactured a starship or whose jump technology influenced it based on the pattern of its initial jump field, particularly visible on jump



grids. Imperial and Solomani ships, as well as pre-Imperial Vilani ships, typically employ a square or rectangular mesh sometimes mockingly referred to as a checkerboard. Zhodani starships tend to use a triangular mesh. Droyne ships utilise a hexagonal pattern, with a few pentagons scattered in to allow for proper tessellation over their surfaces. Aslan ships instead use curving, swirling lines, with whirls and spirals reminiscent of the calligraphic yoyeaokhtef that adorn their interior walls; Aslan engineers find it easy enough to follow these patterns that they are no harder to maintain than 'boring' Imperial designs. Vargr ships rely on an evenly spaced but otherwise completely anarchic setup; the trick to maintaining these is apparently to treat each section of the hull as its own thing and follow the 'advice' it gives rather than trying to impose a single uniform solution on the entire ship, similar to how any large Vargr group works. Hiver vessels utilise complex, intricate moiré-like grids with overlapping elements, which can be quite dazzling to the eye when activating. The K'Kree use a grid of parallelograms likened to 'blades of grass' on their saucer-shaped vessels.

JUMP INTRUSIONS

A 'jump intrusion' is when the jump field collapses and intersects the hull, most often mid-jump after field inflation. All recorded misjumps that involved jump intrusions showed them progressing in either a steady advance or a 'pulsing' rate with brief increases in the rate of intrusion coupled with temporary slowing or reversal.

While a jump intrusion can cause a wide variety of problems, the crew should deal with it like a hull breach. The affected areas exposed to vacuum should be evacuated and sealed off. This breach may spread, so plan according to how long each part of the ship has left. If there is a room that projections show will remain untouched, plan to gather there. Failing that, meet in vacc suits in whatever area will be least affected and have materials to patch the breach once out of jumpspace; the jump intrusion will vanish immediately upon jump exit. The damage is done but it will not deteriorate any more. Plan to have a distress beacon broadcasting the moment you exit jump.

If projections show complete collapse of the jump field, a ship's only hope is to have a way to slow the jump intrusions down. Most often, it will involve stopping whatever caused them in the first place. If the intrusions progress significantly, reaching them may require unorthodox methods such as cutting through bulkheads or passing through exposed areas during a low pulse. If the crew can eliminate the source, it may be possible to use the jump field subsystem to reinflate the field, especially if there is leftover fuel. While past the most critical danger, the starship will have suffered heavy damage, likely with life support partially compromised. Surviving crew and passengers will not be 'safe' until aboard a rescuing spacecraft or port.

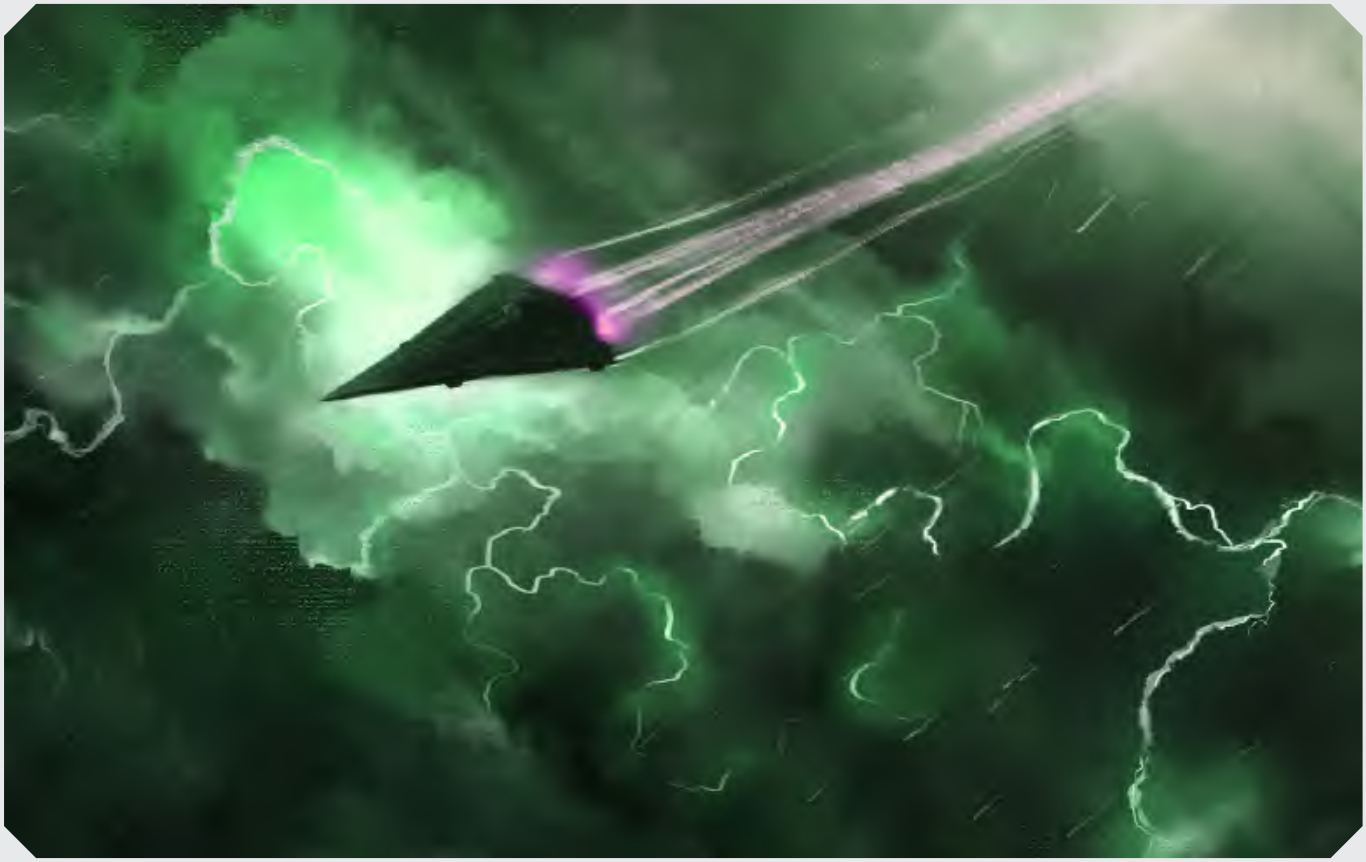
Prevention is the best cure. Fix malfunctioning equipment and do not use it until repaired, despite the idea that fixing it would be too expensive or bothersome. Some point to statistics or anecdotes that show ships with these equipment issues still fly well but that is a survivorship bias error, as these statistics and anecdotes only include ships not lost to jump intrusions.

MAINTENANCE AND UPGRADES

When bringing a ship into a starport for annual maintenance, the technicians pull each of the drive elements and test them individually. Ships that use ongoing maintenance instead of annual maintenance test units in a rotating schedule between jumps, replacing failing or substandard units. This level of modularity benefits the jump drive industry.

Occasionally maintenance issues become apparent during the creation of the jump field. Even with computer control, the field sometime brushes against the hull, causing micrometeorite-like dings. Unclogging the hydrogen injectors is another common maintenance headache due to large numbers of them, even on a relatively small *Suleiman* hull, which spend most of their time exposed to vacuum. While they squirt tiny amounts of hydrogen, occasionally larger debris sticks and clogs the injectors in a manner akin to particles lodged in pores on skin. This results in no end of references to engineers giving the ship a spa day. Freezing and clogging the injectors is the most common means by which impurities in unrefined fuel interfere with jumps.

Upgrading a ship's jump rating typically means buying a new jump drive. If absolutely necessary, a jump drive can be rebuilt or upgraded piece-by-piece, although it is not recommended as trying to modify a non-native component to work with other systems can be more expensive than buying a new jump drive to begin with. Upgrade the power conditioner first to handle the additional power drawn from the power plant, then the control system. Most starships have drive/shunts designed for multiple jump levels at that



particular ship's size class but sometimes shipyards replace it entirely. Finally, upgrade the jump field subsystem to handle the increased hydrogen required to maintain the field. If all goes well, the jump drive now takes the ship farther.

While maintenance is important, making sure the jump drive is undamaged and has enough fuel and supplies for its mission should be a high priority before making the jump as not all destinations offer resupply and jumpspace offers no such opportunities. When entering a new system, a ship can scan for a gas giant or area with sufficient water or ice, which gives an excuse to scout a bit before landing or continuing with the mission. Some leave that job until it is time to go, which can cause problems if the ship needs to leave quickly, as refuelling can be a time-consuming process. It is best to start preparations for restocking as soon as possible. While an astrogator is working on calculating the next possible jump, it is often a good idea for them to identify a couple of routes out of the system in case of emergency.

THE SCOUT

While most believe a scout on a ship like the *Suleiman* would rely mostly on sensors, the truth lies closer to the jump drive. While it varies by their mission, most spend at least half their time in jumpspace, particularly those on courier duty. The wide-open space and long runs are what many scouts love about their job; if you do not like jumping, scouting is not for you.

One does not have to know all those theories of how the jump drive works to use it, only what needs to be done to start it up again quickly for the next jump. Too many times a scout gets into trouble by not knowing the steps required to jump or without making sure they can load enough fuel on board to move the ship out of a hostile area. Sometimes one can leave quietly and peacefully but preparing ahead of time has saved many scouts. Scouts should always keep an emergency jump route in mind as it is amazing how quickly a system can turn hostile after delivering a vital piece of information.

REACTION DRIVES

Properly defined, reaction drives are any part of a spacecraft that moves the spacecraft through direct reaction with mass. This excludes gravitics or any other reaction with an energy field, as well as another spacecraft docking and applying its drives.

Like jump drives, most reaction drives consume fuel. Unlike jump drives, reaction drives deliver relatively little movement, and lifters and manoeuvre drives render reaction drives obsolete for most purposes. Most starship crews will never personally encounter reaction drives but it is still useful to know about them. It is distressingly common for those with no personal starship experience to assume that starship crews know about all manner of space systems, even ones not used on starships. Reaction drives are particularly susceptible to this, especially on worlds where gravitics are not available so reaction drives are the only means available to reach space.

When reaction drives are present on a starship, it is most often due to one of three reasons, the first two of which are more common among ships designed for combat. First, reaction and manoeuvre drives have a maximum performance generally limited by TL but these are separate limits. Having both systems allows a ship to accelerate at the sum of the drives' performances, achieving much greater acceleration than is possible with either drive alone. Second, some ships use reaction drives as an emergency backup for manoeuvre drives as their failure modes have little overlap. Most reaction drives will continue to function even if the ship loses power, while manoeuvre drives can continue without a ready supply of reaction mass. Third, reaction drives can operate beyond a manoeuvre drive's operational limit, whether in the Oort cloud of a system or light years from the nearest star or rogue planet.

While reaction drives can come with inertial compensation, as described in Ship Internal Gravitics starting on page 75, most do not. Using them without subjects a ship's occupants to G forces. Technically, reaction drives only accelerate themselves and anything they are rigidly attached to, such as the ship's hull, which in turn pushes along its contents, such as crew and passengers. This acceleration acts like gravity proportional to thrust; in most cases this force is substantially more than 1G. The uneven distribution of forces and structural weakness of flesh and bone lead to several health issues with prolonged exposure to high G forces, with more severe effects the greater the force and the longer the exposure. The crew's ability to survive, rather than any technological limitation, dictates the maximum strength of a ship's reaction drive.

One of the simplest ways to illustrate the difference between manoeuvre drives and reaction drives is to consider why Jump Control software automatically locks down any reaction drives during jump. Where a manoeuvre drive would do nothing, having no significant mass outside the ship to react with, a reaction drive works inside a jump field. However, extreme care must be taken as any significant exhaust would severely destabilise the jump field. As this would destroy the ship, there is precedent in Imperial courts that any attempt to activate reaction drives while in jump amounts to an attempt to destroy the ship, which serves as legal justification for lethal force and/or mutiny if necessary to stop this attempt.

ROCKETS

The most common reaction drives expel mass at a high velocity. There have been a number of means employed to achieve this but they work by the same basic principle, where mass is removed from the spacecraft in exchange for thrust. Most rockets have exhaust nozzles that adjust their diameters for optimal performance in atmosphere or space, as well as regenerative cooling that uses a small amount of propellant to keep the exhaust nozzle from melting.

When discussing rockets as a means of propulsion, a primary concern is their efficiency, in how much can they move the attached ship using a given amount of fuel. Due to conservation of momentum, the only way to increase this efficiency is to increase the speed of any expelled mass, referred to as exhaust velocity. As a result, most advancements in rocket technology are measured by increasing this exhaust velocity through direct combustion, accelerating charged particles, or any number of other mechanisms. Few ships employ gravitics to enhance rocket performance, whether because rockets are in use because gravitics are

unavailable or because the reaction drive is an augment to a manoeuvre drive which this might interfere with.

Some rockets have an 'atmospheric mode', wherein they hook fuel scoops to the reaction drive and use air as reaction mass, usually heating it before expelling it. This doubles the cost of the reaction drive, only works within a thin or thicker atmosphere or a hydrosphere and requires that the spacecraft have fuel scoops. The result is perhaps the fastest, most agile in-atmosphere performance manufactured in Charted Space, at a price that is almost never worth it for this capability alone, although there is always some reason that makes the price almost irrelevant.

- Some spacecraft use this method to achieve orbital speed. As this greatly saves on fuel, this may be the most practical means of achieving orbit where these rockets are available and gravitics are not.
- Ships that frequently pursue blockade runners, system defence fighters and similar sometimes have this feature built in during construction to sustain maximum acceleration for longer periods.
- Racing and emergency response craft sometimes justify reaction drives on account of speed being their primary mission.

CHEMICAL

The lowest TL form of rockets, these burn fuel that has energy bound up in its molecules and vent the combustion products. There are many subdivisions of chemical rockets; solid or liquid fuel, monopropellant or bipropellant, pump fed or pressure fed. None of these subdivisions are significant compared to the performance gains from switching to electric or nuclear thermal rockets.

On many worlds these barely reach orbit, sometimes requiring designs that discard sections of the spacecraft on the way up. This makes access to space far less economical, which is the main reason why practical exploitation of a solar system beyond a single colonised world and its moons tends not to happen before the world can manufacture its own gravitics at TL9. Some TL7–8 systems have managed to come up with relatively high performing versions of electric or nuclear thermal rockets and there are rumours of Ancients chemical fuels with a high enough energy density to make chemical rockets competitive with early nuclear thermal rockets.

ELECTRIC

Known as ion rockets, these accelerate charged particles at very high velocities, akin to crude particle beams but without the range – or damage, unless the target is almost touching the engine. As with chemical rockets, electric rocket varieties are similar enough to not merit discussion of the subdivisions available.

Early electric rockets have very limited thrust, being woefully insufficient to achieve orbit, only able to adjust orbit and escape to interplanetary space. However, they are much more efficient with their output than chemical rockets. World-to-world transfers in an inner solar system with an early electric drive providing constant thrust are possible, while a chemical reaction drive of similar TL would have nowhere near the necessary endurance.

A few spacecraft employ advanced electric rockets capable of generating a full G of thrust or a significant fraction, thrusting at this level for most of their journey. Most of these use a tailsitter design with 'down' pointing in the direction of thrust, for the sake of artificial gravity without gravitics. The controls and layout are designed to facilitate zero gravity operations as well, for those times when the spacecraft is not in motion.

Some differentiate 'nuclear electric' from other types, as the greater density of power available from a fission or fusion power plant makes greater thrust and endurance possible. This helps distinguish it from nuclear thermal propulsion.

NUCLEAR THERMAL

The hotter the exhaust, the faster the propellant leaves the ship, the more efficient the rocket. The highest temperatures achievable are associated with fusion processes. Nuclear thermal propulsion takes this to its logical conclusion, using a fission or fusion reactor to directly heat the propellant rather than convert the reactor's output to electricity.

Those who misunderstand nuclear processes sometimes believe the exhaust of a nuclear thermal rocket is inherently radioactive but this is not practical for multiple reasons. To illustrate this, it is best to distinguish between two types of nuclear thermal rockets. 'Open cycle' rockets have no shielding between the nuclear process and the fuel, so the reaction mass is directly exposed to the fusion or fission processes and picks up radioactive elements. 'Closed cycle' ones have substantial shielding – blocking alpha and beta particles while allowing as much heat as possible – so the exhaust is not substantially radioactive.

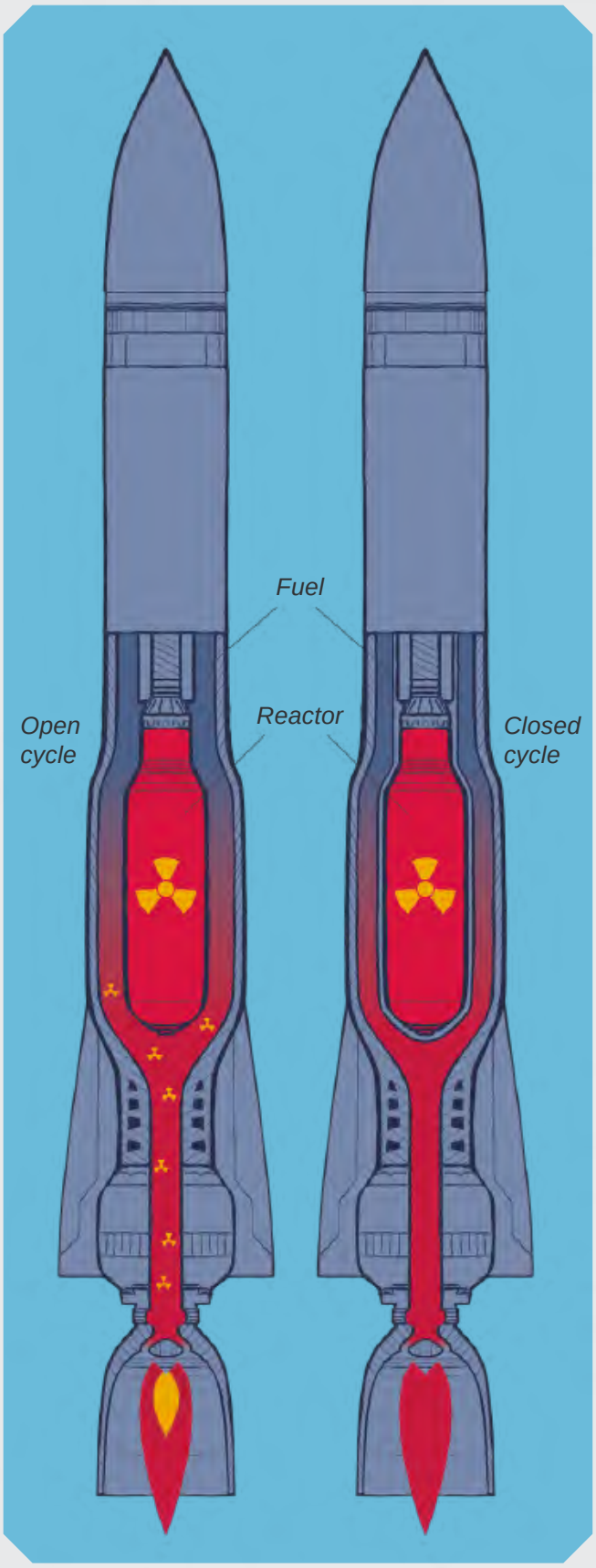
Open cycle rockets would be more efficient if one looked solely at power and mass per unit thrust. However, operating in this manner irradiates the

engine, requiring costly replacement after several hours of use. More importantly, almost no inhabited world capable of controlling its airspace allows the operation of open cycle reaction drives anywhere near their world where fallout could reach areas they wish to protect, although closed cycle drives are allowed. This ban on open cycle drives is treated as seriously as the ban on the use of nuclear weapons near populated worlds in Imperial space, although technically it falls to individual worlds to enforce.

It is generally not efficient to conduct a full fusion cycle and use the resulting helium as reaction mass, although some drives do. Among the issues is maintaining the larger nuclear damper field needed to cover the entire engine. Rather, most nuclear thermal drives use a separate dedicated reactor to heat hydrogen pulled from the same fuel tank that services the main power plant and, on starships, the jump drive. This allows spacecraft to trade off jump capability, operational endurance and reaction drive performance. Some fighters make an art of this, the same fuel tank allowing for either an extended patrol using only manoeuvre drive or high speed but limited duration combat operations.

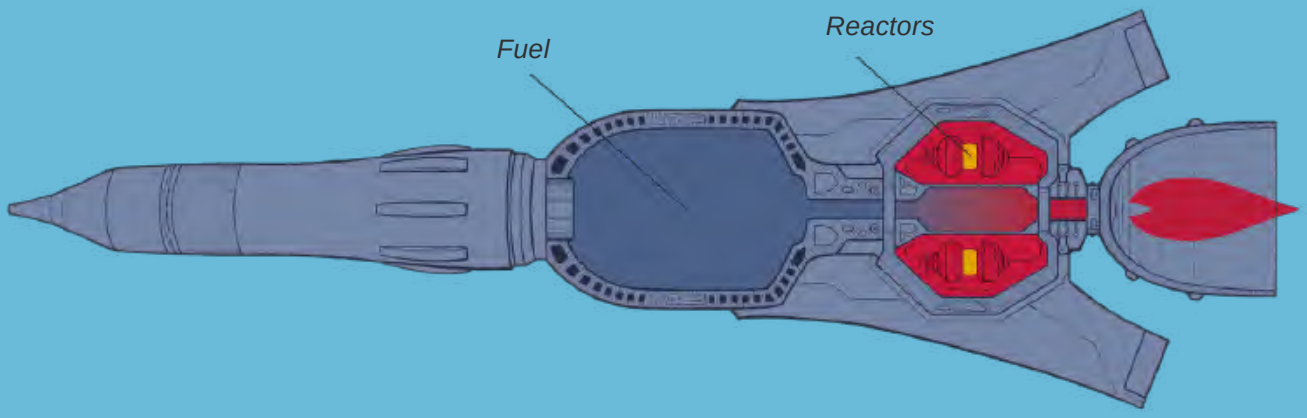
Nuclear thermal drives are the most common form of reaction drive in modern ships due to the widespread use of 'HEPlaR', or High Efficiency Plasma Recombustion. It is so common that, if one sees a ship in the Third Imperium with an unidentified type of reaction drive, it is safe to assume HEPlaR unless there is evidence to the contrary. The term became generic, similar to modern fusion power plants being called 'Fusion+' even if they do not precisely follow the original patented formula.

Modern use of the term means a cluster of small fusion reactors – usually three, four, or six – arranged around a central chamber that takes in liquid hydrogen, heats it to a plasma and expels it. Not primarily designed to capture fusion output as electricity, these small reactors use laser-weapon-grade mirrors, superconductors and further means to route more than 99% of the output energy directly into the propellant. The remainder is waste heat, partly used to spin turbines to create electricity used to recharge ultracapacitors that start the fusion reaction and to manage the system. Like most rockets, HEPlaR is fully independent of the ship's power system, needing no external energy to start or maintain.



NUCLEAR THERMAL DRIVES

HIGH EFFICIENCY PLASMA RECOMBUSTION



Plasma recombustion refers to the exceptionally efficient transfer of heat from reactor to propellant. However, 'High Efficiency' and 'Plasma Recombustion' stress the same point. When introduced, the official explanation was the system was just so efficient at transferring heat that it justified the name. While the system is very efficient, that is not the entire reason this label became popular.

HEPlaR started as a marketing term for a specific type of nuclear thermal drive. Like Fusion+, it was not technically invented by Cleon I but popularised during his reign. HEPlaR started out as one of the many applications of Fusion+ that made this new generation of fusion power plants so attractive. It was arguably the second most successful such application, after power generation. Its success greatly assisted Cleon I's economic and technological ambassadorship that was vital to the Third Imperium's early growth to the point that some misattribute its creation to Cleon I himself.

As with Fusion+ power plants, there remain enough technical similarities between modern HEPlaR drives and those manufactured around the founding of the Third Imperium to justify retaining use of the name, but the primary reasons are tradition and pride. It is theoretically possible that someone will someday invent a radically different and much better reaction drive that none would call HEPlaR. Today is not that day.

OTHER REACTION DRIVES

As with most spacecraft technologies, time witnessed the invention of a wide variety of reaction drives. While a number of supposed reaction drives have turned out to be complicated manoeuvre drives, there have been a few non-rocket reaction drives.

THE T-DRIVE

One famous example of a non-reaction drive is the 'Reactionless Drive', known as the T-Drive. Allegedly, it turns rotational energy into linear thrust. In truth they are fancy manoeuvre drives which sacrifice efficiency and performance.

T-Drives are notorious for being based on a truly ancient mistake, the hypothetical Dean Drive of pre-spaceflight Terra. Despite similar claims of turning rotational energy into linear motion, the Dean Drive was in fact reacting to friction with whatever surface it was mounted on. Likewise, most demonstrations of the 'reactionless' T-Drive fail to account for nearby gas or plasma the drive pushes away.

This is not to say that T-Drives do not work, just that they are not properly reaction drives.

COLD GAS

Cold gas thrusters store gas at high pressure then vent it. They are similar to a rocket, except the propellant is not significantly heated. The gas is not moving at a substantial velocity, generating no significant amount of thrust. This approach is only useful for short-range manoeuvring and changing facing, although is majorly less damaging to its surroundings than other forms of reaction drive, especially if used in port in close proximity to other ships. Given its inability to impart significant thrust, many consider this not a proper reaction drive.

Directing helium vented from power plants and opening pressurised airlocks to depressurise in a given direction fall under this category. Some spacecraft use a small reserve of helium, recharged from the power plant as necessary, as a backup means of changing facing, particularly to counter spin imparted on the craft by external forces.

SAILS

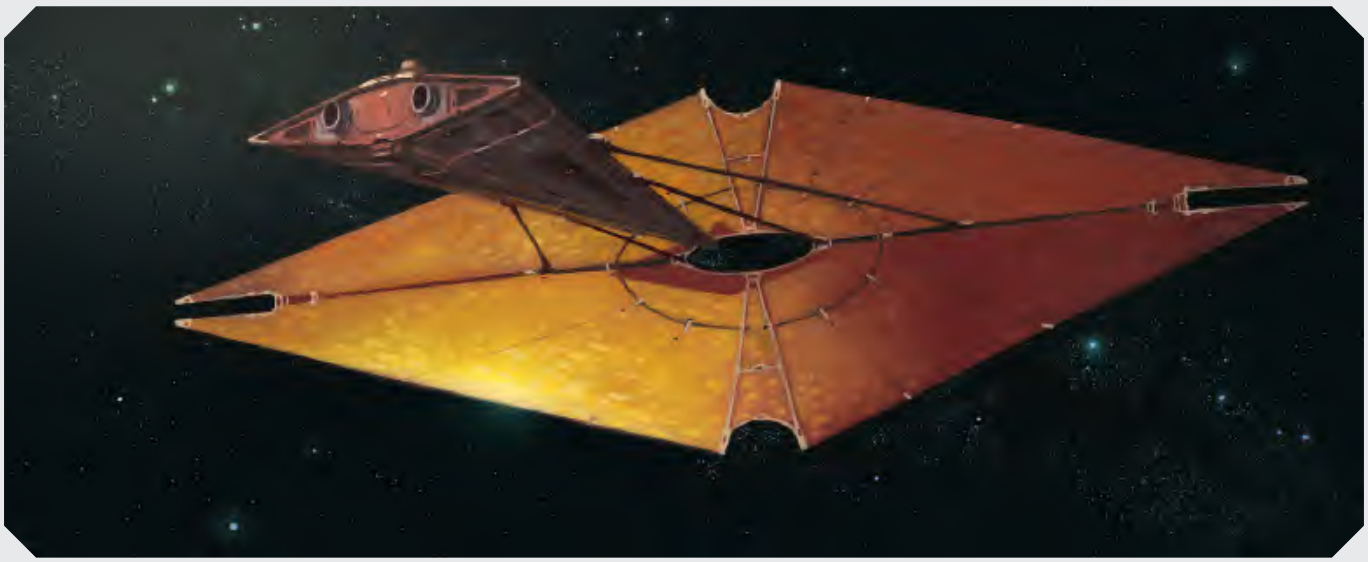
Deflecting masses of particles flowing around a vehicle to provide propulsion is, by some measures, the defining technological advancement of TL2 when applied to waterborne vessels. Almost every civilisation that independently achieved spaceflight has experimented with the same principle, even if solar winds are much thinner than the winds of any significant atmosphere.

Some sails are simply large, thin and light structures that cover a large area. Others are partially or entirely magnetic fields, as solar winds typically consist largely of ions that magnetic fields can readily deflect. Either way, pushing away from the local star is easy, while getting closer involves ‘tacking’, deflecting the wind to approach at an angle, going back and forth so the overall course heads toward the star. Orbital mechanics play into this as well. Accelerating or decelerating on a vector perpendicular to the direction the star is in can cause a spacecraft to drift toward an orbit further away or closer in.

Sails are arguably the closest thing to a truly reactionless drive presently available. They take no fuel, although they are much slower than most other options so fuel to power life support over the extended voyage is a consideration.

Some systems set up lasers to push sails quickly between worlds, forming an interplanetary mass transit system. Laser-pushed sails have been considered as an alternative to jump drive for interstellar flights, although beam dispersion over light years means this would be an extraordinarily slow process. It would take hundreds or thousands of years, long enough that many efforts are prevented by concerns over whether those who would send forth these craft could keep the laser shining for the entire duration. Many other efforts have been terminated once jump drive became available, by ships visiting the craft in deep space to ‘rescue’ those aboard, loot the ship or commit simple vandalism.

Sails not pushed by lasers are mostly used for nobles’ or high society spacecraft, where their inefficiency and the unusual piloting skills required are seen as an upper crust affectation, much like waterborne sailing on Regina. Some ships bring sails as a backup drive, particularly those exploring unknown or potentially hostile systems that may watch for signs of manoeuvre drives but ignore other data that might signal incoming ships out of complacency or hubris.



Weapons and Defences

Readers of this book, if they ever encounter space combat, are much more likely to be involved in battles with only two or a few ships, each of which has only a few weapons. Having the right weapon on hand and defences against hostiles can make the difference between surviving an ambush and becoming a cloud of debris.

Calibrate weapons regularly, if the ship has any, as part of maintenance. Installation with a misalignment of a hundredth of a degree can ensure nonstop misses, especially when knocked around by fuel scooping or from a hard landing. Single practice shots at low power are generally sufficient to detect and measure this drift, allowing the computer to adjust for it when firing. No other work is required outside of annual maintenance, where the shipyard can correct these errors, which may save the crew's life if the weapons are ever required. It is extremely difficult to carry out during actual fights, which rarely come with much warning for small ships.

Close Support

Although firing ship weapons into personal melee is not recommended, there have been times when someone who is sitting at a gunnery turret, having been confined to the ship while a battle happens outside, wishes to support their allies. If one has to do it, lasers are the best type of weapon given their accuracy, although even lasers have a blast radius caused by ejected debris. The exact limit of this depends on material struck and the laser's energy content at impact but it is possible to estimate the dangerous area and aim so this includes the opposition but not the gunner's compatriots. It is much easier to do this when there are several metres between those the gunner wishes to doom and those they wish to save.

Rarely will a captain give an order to fire on a hostile ship as part of boarding actions. Firing will punch holes in the hull and depressurise the ship, sometimes while the boarding crew is aboard. Any boarding party should wear vacc suits in case this happens. If you are boarding a ship, you mainly want the ship intact. More importantly, this legitimises return fire directed at the turret, should the other ship have any functioning and crewed weapons.

Weapon Mounts

For the reasons given in Hardpoints and Firmpoints on page 9, a 100 ton ship will have at most a single weapon mount while a 200 ton ship will have at most two. Captains of such ships must carefully select which weapons they will carry, if any. While an unarmed ship can enter some private ports that forbid visibly armed ships, no public starport in the Third Imperium can afford such a restriction and there is the option of using pop-up turrets to appear unarmed. However, not all weapon mounts are equal.

Firmpoint and hardpoint mounts have different standards. Hardpoints generally provide more power and structure for heavier recoil. Although firmpoint weapons could mount to hardpoints where they would underperform, it is a good rule of thumb to assume the two types are not compatible.

Turret

A slightly external mount that is able to track and swivel to point a weapon at a target, turrets are the standard option for small ships, easily dismountable with standardised fittings allowing quick replacement at most starports with the proper equipment (any Class C or above and some Class D starports). Up to three weapons can be mounted in a standard size turret, although it must carry sufficient power couplings, fire control and structural reinforcement if it is to carry a full trio. Some claim to have mounted no less than four weapons onto a standard turret, although the authors of this book found no surviving examples in their research, suggesting this may not be a wise decision.

The standard templates for the ships in the Ship Walkthrough chapter include turrets only rated for two weapons each, with actual purchase and installation of weapons left to the ship's owner post-construction. Many

owners never bother as starship-scale weapons are expensive, with costs typically measured in Megacredits per weapon. Some captains use relatively easily installable, removable and resaleable turret weapons as portable currency that serve a useful function to boot. Others utilise turrets for things besides weaponry; directional sensors or drone launchers are a common choice, particularly on scouting or exploration craft.

Pop up varieties retract into the hull when not in use, making the ship appear unarmed. Detailed scans will find these only at close enough range that hostilities would have already commenced. Aside from stealth and ambush, these can create a polite fiction when dealing with ports that can afford to turn away armed traffic. It is useful to assume that every apparently unarmed ship at such a port has pop up turrets and is willing to blow away troublemakers at the Port Authority's request.

FIXED MOUNT

Essentially the same as turrets, these are cheaper to install. The trade-off is that they are less useful when fighting up close – see Point Defence and Dogfighting. For weapons only used at significant ranges where it is easy to point the ship at the enemy, these often make economic sense. Almost all fixed mounts have a small range of motion but for the most part the ship must turn to point these at a target. Most fixed mounts will accept standard turret weapons, to a maximum of three per mount. Pop up fixed mounts are available.

BARBETTE

Known as 'heavy turret' mounts, barbettes are not modular and straddle the border between civilian and military grade armaments. It often takes connections or unusual circumstances for a civilian ship owner to be able to acquire one, whether as part of a ship or an upgrade, although there are always shipyards willing to overlook regulatory issues. They are rarely worthwhile and uncommon except for ships expecting to engage in ship combat on a regular basis or those who would benefit from deterrence. More than one pirate has turned away when the outline of a ship at the extreme edge of sensor detection sported a barbette.

BAY

Rarely found on commercial ships, this is a designation for any sizeable collection of weapons larger than a barbette but short of a true spinal mount. In some cases, the difference is merely one of scale; there are 1,000 ton ships wrapped around a single large weapons bay, much as capital ships wrap around their spinal mounts. While bays have some movement, it is rarely anywhere near a turret or barbette and many consider them comparable to a fixed mount. Some large ships will mount these bays in oversized turrets but most consider this unnecessary as the ranges at which bays become useful are generally long enough that even limited movement is sufficient.

SPINAL

Spinal mount weapon systems are massive, comprising thousands of displacement tons without counting power or support systems. To use these, the entire ship must point at the target, although there are subsystems within the weapon to assist with precise aim.

Spinal weapons have a hard time hitting a ship as small as 100 or 200 tons, which may give a small ship a chance to flee and jump away if they come under fire. The most useful advice this book can give

about surviving an attack by a spinal mount weapon is, do not put the ship in the line of fire. Assuming that 'if it fires and hits, the crew will be dead' is a useful approximation and can be sufficient motivator to talk a way out of a situation before it comes to that.

Bay and spinal mount weapons are used in the defences of larger spaceports. The most well defended Imperial worlds have spinal grade meson cannons buried deep underground, where they can fire through the planet to destroy threats anywhere nearby, even on the far side of the world. Only other meson weapons or special operations infiltrating the weapon sites stand a chance of disarming the defences. Smaller spaceports may have barbettes or turrets, if they have defences at all. Unarmed spaceports are frequent buyers of surplus turret weapons unloaded by ship captains, although most spaceport administrators are aware those captains often wait until they are in distress before parting with their weapons and accordingly offer low prices or favours in lieu of Credits.

PLACEMENT

Although the majority of this book's audience will only use the weapon mounts that come with their ship, if any, some will wish to install new ones. There is a question of where to mount them, the answer to which can be complicated.

To ease the process, consider each weapon mount in terms of its arc of fire. Fixed mounts will have a limited degree of movement, while turrets or barbettes will have almost unlimited arcs, stopped only by the hull. Spacecraft with only one weapon mount will find the decision trivial; the firing arc should cover the forward axis to ease aiming and, if a turret is mounted, cover as much of the ventral or dorsal side of the craft as possible. Dorsal mounts are usually preferred as they facilitate firing while landed. Ventral mounts are desirable if using the spacecraft for ground attack, generally only a concern for mercenary or military units.

Consider a spacecraft with two turrets, one each on the dorsal and ventral sides, both limited to a 180° arc of fire. These turrets, mounted on flat parallel sections of the hull, grant almost 360° coverage, barring a narrow plane between the sections. However, only one turret could fire on a target at any given time, thus having no convergence. Alternatively, these turrets could be mounted on a section of the hull more sharply angled forwards. This would limit coverage to the aft but would allow both turrets to fire upon targets, granting greater convergence to the fore. Some roughly liken this to primitive fauna using either monocular or binocular vision. The *Empress Marava*'s starboard-fore and port-fore turrets are a compromise between coverage and convergence, albeit on the port and starboard surfaces rather than ventral and dorsal.

For the overwhelming majority of spacecraft with more than one weapon mount, prioritise convergence. Although coverage is critical for point defence against missiles and light craft, most engagements take place at a long enough range that manoeuvring and spinning to allow every turret to fire on target is feasible. Non-military exceptions are practically non-existent.

TYPES OF WEAPONS

An exhaustive treatise on the many kinds of weapons used in space combat over the millennia would be larger than this book. To usefully classify the vast and diverse array of shipborne weapons in Charted Space, it is necessary to group many types into a few categories.

One common equation relevant to weapons engineers is for kinetic energy, $K_E = ½mv^2$. In Galanglic, 'the kinetic energy of a projectile is equal to half the mass times velocity squared'. Armament engineers have to work backwards from that. They have a maximum energy budget, minus inefficiencies in the weapon's launch mechanism. Energy requirements for a (physical) projectile increase linearly as the mass goes up but quadratically as velocity increases. Space warfare demands the highest possible muzzle velocity achievable to allow accuracy at long range, even at the cost of projectile size, thus one can trace the history of weapon development as incremental increases in muzzle velocity coupled with substantial decreases in projectile size.

Missiles propel enormous warheads, hence why more than half of a missile is its m-drive. Slugthrowers suffer as well, as there is generally a minimum size requirement per projectile due to constraints of the specific launching systems. Bombardment slugthrowers tend to use heavier projectiles and lower velocities, while dedicated space combat slugthrowers like sandcasters go as small as possible. Plasma and fusion weapons take this further, firing a minimally sized gas at outrageous velocities and relying on temperature to do additional damage. Particle and meson weapons reach the extreme of what is possible, such as firing individual particles at high fractions of light speed. Lasers sidestep the issue by using massless photons that travel at lightspeed.

LASERS

These fire beams of coherent photonic energy, the simplest forming it by bouncing energy back and forth through a chamber with mirrors on either end until the energy is all going in the same direction and has

the desired intensity. More advanced versions use variations on this such as bouncing light between thin reflective layers individually less than a micron thick, one accepting electrons from another and creating photons in the process that stimulates more electrons until the light finds its way out the side. Some speak of 'masers' where this energy is in the microwave frequencies or 'grasers' for gamma ray frequencies but the basic principle remains the same.

Lasers come in 'beam' and 'pulse' varieties, which either fire one continuous beam or break up the energy into separate pulses. The latter do more damage because vaporised material tends to reflect and absorb some of the energy of a continuous beam; firing in pulses gives the material time to disperse, allowing more energy to strike the target. Either way, the fact that this damage is done over time rather than in one concentrated burst means sandcasters can be an effective defence against ship lasers.

Since the 'projectile' of a laser is light, all the tricks to manipulate light will work on a laser so long as they can handle high intensities. This is the primary reason why people rarely attempt to bounce weapon-grade laser beams off mirrors to achieve indirect fire. In particular, this includes using gravitic lensing to focus the beam so it remains at deadly intensities over much longer ranges, although there is almost never a gravitic lens at the target.

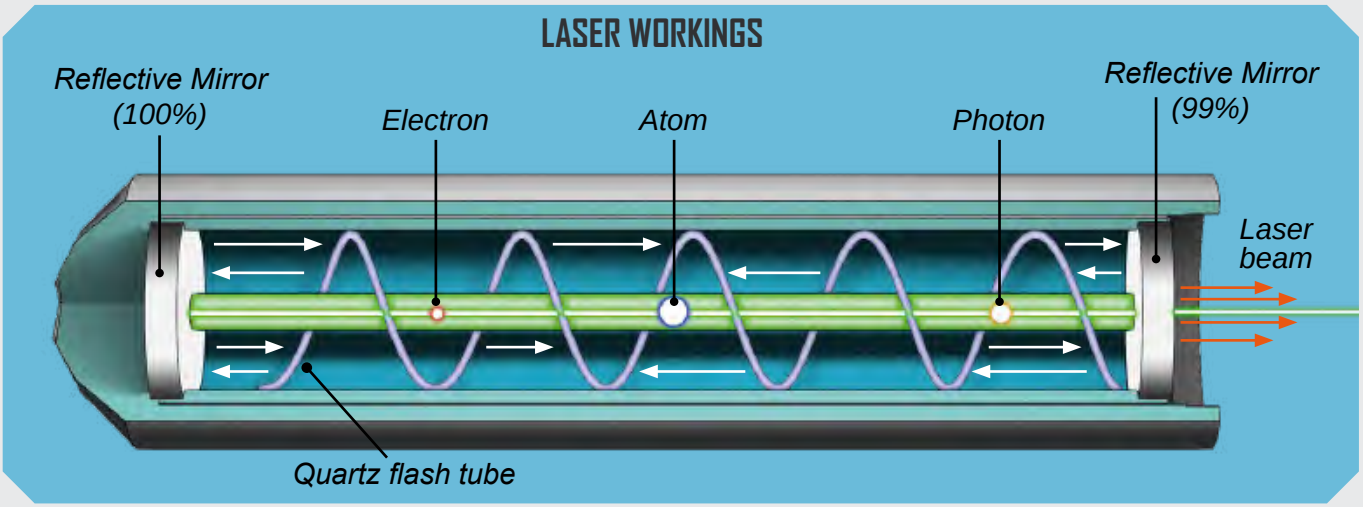
Lasers are by far the most common turret-based weapon. This is partly due to their use in point defence, as heavier lasers do not track quickly enough to shoot down missiles. Laser drills not intended as weapons have seen use in countless combats as a beam powerful enough to shred asteroids is entirely capable of shredding ships, if it can hit. Hybrid approaches that 'detune' a laser for mining then 'retune' if combat happens have seen limited application, generally winding up stuck in one mode and becoming ineffective beam lasers or very expensive laser drills.

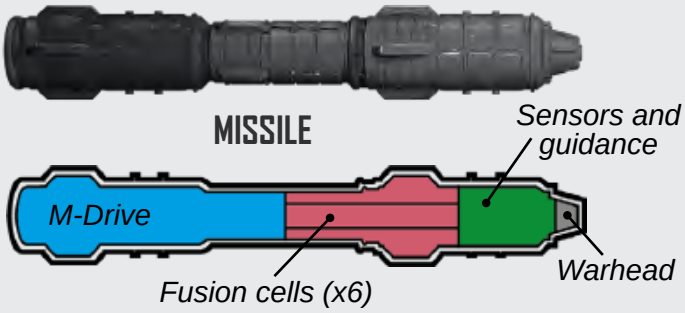
MISSILES AND TORPEDOES

A logical extreme of drone warfare puts warheads on disposable craft that hurtle toward a target. Larger versions are missiles intended for bigger targets, called torpedoes. There are a variety of warheads, from simple kinetic-kill intended to capitalise on a missile's velocity to explosive penetrators, nuclear, electromagnetic pulse, decoys, shrapnel interceptors and more.

Missiles have two properties. First, a large volley of missiles is the most reliable way to destroy a target in one hit, from beyond the range where most other weapons can respond. Second, missiles are expensive and a ship can only carry so many at a time, making them uneconomical for most commercial ships. Missiles are generally designed to burn themselves out in operation with no expectation of recovery. Most missile-like objects intended to be recovered are referred to as 'probe drones' or other terms to reflect the difference. There have been cases where the cost of a volley of missiles exceeded the price of the asset they destroyed. One of the defences a small ship has against this is being less expensive than the missiles and not being worth expending one. Ship captains intent on annoying those who possess said swarms would do well to keep this in mind and limit how annoying they are.

Given their cost, missiles have a reputation as a 'high end' weapon. Common pirates are unlikely to be able to afford them, if they even have means to obtain resupply. It is a well-known gambit to fire one missile – easily shot down – to convince a ship to surrender.





Some ‘dummy’ missiles are designed explicitly for such scare tactics, with no warhead but instead designed to miss and be recovered.

SANDCASTERS

Sandcasters throw collections of small particles using large arrays of tiny slugthrowers. Their primary use is to block incoming laser fire. Although they cannot be fired before the laser hits, it is usually perceptible which direction laser fire will come from and since lasers do sustained damage over time, sandcasters can block all but the very start of an attack. This default use slightly varies the angle of fire from particle-to-particle to make a more effective blocking cloud.

There are other, less common types of sandcaster loads. Most fire at high velocity, earning sandcasters the nickname ‘deadly rainmakers’, although like slugthrowers this is substantially less than the speed of light, which greatly limits their effective range. Anti-personnel uses are the most well-known, whether against would-be boarders or for military ships to give nearby troops close air support.

Sandcaster barrels have variable apertures, using mechanisms similar to time-tested iris valves to move the magnets that accelerate each particle further apart or closer together to achieve larger or smaller diameters. This assists with maintenance and accommodates variable munition sizes, especially for alternative sandcaster ammunition. If a particular barrel malfunctions, it can cycle shut to prevent it from wasting ammunition then signal the ship’s computer for maintenance when the sandcaster is not in use. Minute adjustments to part of the barrel can adjust the aim, such as shrinking the top or bottom half a little more than the other to aim vertically, imparting slightly more acceleration in that direction.

The lower cost of sandcaster ammunition makes them more economical than missile launchers but they still are frequently disfavoured on commercial ships, despite their defensive potential. Nonetheless, they even have non-combat roles, such as loading them with sprays used for agricultural use or to deploy ‘smart dust’ sensor microdrone swarms. One tale tells of a captain who loaded confetti rounds into his ship’s sandcasters to help announce his ship’s arrival shortly after breakout from jump. His ship was some distance from port, so traffic control misinterpreted this as debris, thought it was breaking up from a post-jump mutiny, and dispatched marines to rescue the passengers. Things escalated from there.

PARTICLE ACCELERATORS AND MESON GUNS

Primitive particle accelerators capable of smashing particles together at point blank ranges under highly controlled conditions are available even at mid-industrial pre-stellar Tech Levels. Those that can direct a coherent stream of particles at ship combat ranges, in large enough quantities to inflict significant damage while being small enough to mount on a typical starship, require substantially higher technology. Many of the advances are similar to those that make gauss weaponry viable and many think of a particle accelerator as a coilgun with smaller projectiles and higher energies.

However, there are nuances that are well understood, such as the difference between firing through vacuum, where particles must charge neutrally or they would force each other apart enroute to the target, versus firing through atmosphere, where particles are better off charged to deflect the air and use it to keep the particle beam together. Although the particles travel slower than a laser’s light, they are close enough to light speed that they can be used in much the same way. Relativistic time dilation does not matter much to the particles so long as it does not cause decay before the payload arrives at the target.

One exception comes in the evolutionary line of particle accelerators, the meson gun. These fire unstable particles that disintegrate fractions of a second after generation. They are not actual mesons, although the name stuck from early counterintelligence operations obscuring it. Without relativity, this would happen shortly after exiting the weapon, if not within the weapon, giving far too little range to be useful. Careful control of speed and thus time dilation causes this decay to happen at much more distant ranges, spread along a segment of the line of fire. Further manipulations using an evolution of the nuclear damper causes the particles to decay over a very narrow band of time, rather than spread out with an average half-life as they normally do. As these particles do not interact with matter until they decay, the result, if properly aimed, is an explosion along a line segment within the target regardless of anything in the way, such as

armour, other ships, or even kilometres of solid rock. Unfortunately, meson weaponry is usually too large or expensive for practical application aboard small ships.

The meson gun's ability to bypass any armour or other defensive systems mean there are virtually no reliable countermeasures to meson weaponry prior to the invention of the meson screen, aside from making sure you are not hit by one. Because of this, the meson gun earned its Vilani name *Gashukubi*, translating to 'certain death', from the fate of the Vilani scouts who first met with this weapon. The name proved prophetic; it was the development of the meson gun by the Terran Confederation combined with development of the jump-3 drive, made manifest in the *Indomitable*-class battleship, which eventually ended the Interstellar Wars in the Confederation's favour.

ION CANNONS

A special type of particle accelerator, ion cannons do not inflict much damage – radiation or otherwise – but instead overload a target's power systems. The mechanism of operation is quite similar, differing mainly in the type of particles and that they typically carry a strong electrical charge.

Usable with fewer consequences than other weapons, they are only supposed to interrupt power temporarily with no lasting damage. However, just as 'stun' weapons for personal combat are more accurately described as 'less lethal', so too can ion weaponry cause problems in certain circumstances. For example, disrupting power, thus shutting down the manoeuvre drive, on a ship landing on or taking off from a world may lead to a fatal crash.

PLASMA AND FUSION GUNS

Plasma and fusion guns have similar results but operate differently, although both are a distant descendent of slugthrowers in that they physically propel mass to hit a target. Optimised for extremely high speed and low-mass delivery of gravitically-confined plasma, these weapons cause damage both through direct impact energy like a rail cannon and the input of additional thermal energy.

Plasma guns consist of three main components. The plasma source provides and superheats gas to high but non-fusing temperatures. It squeezes through a high gravity column, which pushes on the sides of the plasma to minimise movement except along the intended direction of travel. The end of this column accelerates this 'plasma laser' at the target. The result falls apart a few seconds after leaving the weapon's emitter if it does not strike a target, which limits effective range. If it does hit, the coherent plasma bolt does more damage than a dispersed cloud would.

RADIATION

Notably, particle weapons, as well as certain other types, dose their targets with high amounts of radiation in addition to dealing conventional damage. Radiation damage remains somewhat controversial despite thousands of years of use, as it has different applications. Specifically, it sickens and debilitates sophonts, causing them to suffer if they do not die outright. Lingering radiation can leave a ship and its cargo unusable as salvage, which is one of the reasons these weapons are unpopular among pirates.

Anti-radiation treatment is possible but takes time and can be expensive. Most shipboard medical bays, particularly on non-military ships, are only equipped to treat radiation sickness slowly. Ship crews that expect to frequently encounter high radiation, whether in combat situations or operating near stars that have a high incidence of solar flares, often upgrade their medical bays to deal with this. Nuclear dampers can mitigate the worst of radiation damage but they are of little use for decontamination.

Fusion guns are all of the above but have an additional component. Plasma weapons lose damage at range as the superheated gas radiates and cools. Fusion guns handle this by including an integrated nuclear damper in the weapon to lower the minimum temperature to the point the plasma is self-burning and maintains heat for much longer. The increased fusion rate lasts long enough to hit a target, unless an opposing nuclear damper defending the target overrides this by dramatically increasing the fusion rate so the bolt burns out before impact.

Viewed as compromise weapons, these have projectile mass, energy and an effective range between lasers and slugthrowers.

A fusion weapon can be used as an emergency power plant, in the same way as an m-drive can be used as a gravitic forge. It takes work, adding energy-

harvesting equipment, reconfiguring the gravity column and nuclear damper. It will be less efficient than a purpose-built fusion power plant of equivalent tonnage and attempting the conversion runs the risk of making it unable to serve either purpose, but is an option if something destroys the main power plant.

SLUGTHROWERS

While this category includes chemically propelled munitions, most slugthrowers used as ship weapons feature electromagnetically or gravitically accelerated projectiles. Effective range is short, making these useless in most cases; by the time they would be in range, one side is defeated and the battle is over, although very fast spacecraft such as fighters can manoeuvre into range quickly. Limited ammunition is another drawback, although most carry enough to last for multiple engagements. Typically used for orbital bombardment, these have the inertia of a kinetic slug and can cope with atmospheric interface better than many energy weapons; a laser weapon firing through a raincloud or similar will bleed off energy, reducing potential damage. However, even purpose-built bombardment ships often prefer the versatility of missiles or the precise fire of meson guns.

TRACTORS/PRESSORS

Among the mechanically simplest of weapons, these 'broadcast' gravity in the direction of the target, to either attract or repel it. Installers use reinforced mountings, to make sure these units do not tear out of the ship. Some of the techniques usable for enhancing radio communications are applicable to tractor and pressor beams, enhancing range. Smaller versions of these are common among belter ships to draw in ores blasted free by laser drills, although these are too small for offensive use. Generally, only those large enough to mount in turrets or larger installations offer combat capabilities.

DEFENCE SYSTEMS

The best defence is to avoid areas where others are shooting, preferably to be nowhere near combat. Alas, this is not always possible. In addition to defensive weapons such as sandcasters listed above, listed below are some active defence measures one can take.

POINT DEFENCE

Shooting incoming projectiles to detonate or deflect them before they strike is an art form unto itself. Turret-mounted lasers accomplish point defence but there are alternatives such as high rate of fire slugthrowers. There are special point defence turrets available for larger ships, which are incompatible with standard turrets but perform better at the expense of only being useful for this purpose.

ELECTRONIC WARFARE AND STEALTH

Electronic warfare covers techniques including sensory overload and decoy signals, intended to confuse enemy sensors. It is primarily used against missiles, as it can take but a moment's course correction to send one missile into others in its volley or cause it to miss entirely. This can throw off enemy targeting at ranges of hundreds or thousands of kilometres. Despite the name, 'electronic' warfare covers magnetic and gravitic techniques and for every type of sensor, there is a jammer.

Where one can establish a data connection to a hostile target, one can attempt to hack an enemy ship's computers, known as the 'DataCaster' approach. In combat, one can assume the enemy ship will ignore such efforts – unfortunately, sending data toward a foe is useless if the foe is not listening.

NUCLEAR DAMPERS AND MESON SCREENS

'Nuclear damper' is a generic term for several devices that project nodes and antinodes that enhance or to degrade the strong or weak nuclear force, such as by projecting fields of quarks that mediate these forces. When used in reference to ship defences the term usually means ones that degrade the strong nuclear force at some distance from a ship, upsetting the fine-tuning that allows nuclear weapons to achieve supercriticality and cause chain reactions that create their explosive power. These devices can also inhibit the fusion reactions the weapons rely on for part of their destructive power. Meson screens are a variant that prevent meson decay, causing incoming mesons to skip through the protected ship and explode harmlessly outside. As non-military ships rarely encounter these weapons, such defences are rarely worth installation.

Far more small ship crews will be familiar with the miniature and lower TL nuclear dampers that are part of modern fusion power plants than with versions designed for ship defence. Nuclear dampers too short-ranged and weak for ship defence are also used in antiradiation treatments in well-stocked TL10 medical bays. Belters safely mine radioactive ores using non-defence-grade nuclear dampers. Range and power issues aside, shipyards cannot repurpose these for ship defence because they are too specialised. For instance, ones optimised to promote beta decay for neutron manufacture will not defuse most nuclear weapons but might detonate them.

Nuclear dampers are versatile tools. A nuclear damper can prevent a fusion or fission power plant from starting up, force one into shutdown or damage it through power fluctuations. This is usually not possible in space battle, as even the largest damper weapon has to compete with the target's fusion sparkplug and the damper has the disadvantage of range. An ultra-heavy missile might carry one or a raider craft might use one at boarding range but the most common offensive use is at starports. A vehicle with a nuclear damper can drive up to a ship when the crew is not paying attention and prevent them from powering up and leaving. This is akin to gravitic restraints, with the benefit that a trapped ship cannot power its weapons and fire at starport personnel until released.

BLACK GLOBES

These devices of Ancients origin project a spherical force field at adjustable radii around the projector. This globe absorbs energy passing through in either direction, including visible light. Projectiles stop dead relative to the globe, their kinetic energy having been absorbed. Some of the first examples were set to small enough radii that the people who powered them up were cut in half. Authorities quickly distributed recognition manuals and safe testing procedures to keep that from happening again. Most ships have standard library software from the Travellers' Aid Society, which includes these manuals, preventing future dismemberment.

Transferring this energy to capacitors is the main weakness of the system as the capacitors can only hold so much, although they slowly discharge energy while switching off the globe. If the capacitors exceed their capacity they shatter, explosively releasing the stored energy. A secondary weakness is that energy absorption is total and bidirectional. Incoming sensory impressions are blocked just as incoming weapons fire, so the protected ship is flying blind. Gravitic energy is likewise absorbed, preventing manoeuvre drives from interacting with the universe beyond the globe, so the protected ship is drifting rather than flying, hopefully not deep within a gravity well. A common workaround is to set globes to flicker, firing weapons and drives when the globe will be down, although this gives a random chance as to whether the globe provides any protection.

The Third Imperium's most advanced labs have been able to fabricate prototypes, with speculation about more advanced forms such as a white globe that radiates energy while in use. These systems are generally not available for sale for any number of Credits. Favours or theft are required to obtain one.

SOFTWARE ASSISTANCE

Most cultures that invented computers before interstellar contact were already quite familiar with computers' utility for fire control at long ranges. The longer ranges and higher velocities of space combat only exacerbate the difficulty of directing fire to hit a target. Computers are unable to perform as well as sophonts in many shipboard tasks but combat stands out as the exception.

Alas, top end military software and the computers that run it are expensive. Successful commercial operations avoid frequent combat, with the costly repairs it entails, so there is much less opportunity to recover these costs. The best sharpshooter that money can buy may be a program but even military ships can rarely afford the highest rated software. Only the personal ships of nobles and the similarly wealthy may have it.

Mid-range and low-end assistance is another story. There are countless armed merchant ships where the only decent shot aboard is the computer, with crew involved only to select and confirm targets. Sensor operation and piloting are tasks that computers can handle with the proper software, as noted under Drones and Virtual Crew on page 64.

This is rarely adjustable during combat, save to select which program is running should a ship have more software than available computer power. There is usually a best answer for any given situation; for instance, unless a jump is happening or will soon happen, there is probably no need to allocate resources to run Jump Control. The time to decide on appropriate software assistance is while in port before heading into dangerous territory.

MANOEUVRING

A first year pilot may think their job consists only of flying a ship from point A to point B, sitting back if and when combat happens since there is no way to dodge incoming fire. This is not the case, as a pilot's performance can prevent their ship's gunners from doing their job. During a fight, a good pilot will position the ship to allow all weapons to fire on their targets, spinning the ship as needed to bring each weapon to bear while the others recharge, all while evading in non-predictable patterns to minimise successful enemy

attacks. While dodging may be difficult to impossible, not being where the enemy expects the ship to be is more feasible. As the crews of many planet-bound vehicles can attest, gunners and pilots must have clear communication during a battle. This is why military ships run with one gunner on the bridge, although they have a backup gunner at the gun in case of interruption of communications. Small non-military ships need a single gunner per turret as most damage that would shut down intercoms would disable the gun if not destroy the ship. Further, crew tend to have personal communicators that can serve as a backup.

Techniques passed down through the ages eventually recorded, digitised and programmed into commonly available software help with combat tactics. It ultimately comes down to reading the situation and selecting the best course of action. Sometimes this can be just turning the ship slightly to make sure weapons can target better. Other times a ship needs to outmanoeuvre the enemy and escape. These decisions often take split second reflexes to input the commands or allow a fast computer to execute a series of commands to the ship required to outmanoeuvre or outgun an enemy.

INFORMATION

The key to all of this is knowing the enemy. Identifying the type of ship that is attacking provides information that can help the captain and crew decide which tactics help. What weapons does it have and what are their ranges? Which ship is faster? If your ship is slower, can you reach jump limit, port or other safety before the enemy reaches weapon range? If your ship is as fast or faster, you can simply run away, preventing combat so long as hostile intent is deduced before the enemy gets close enough to fire. Small non-military ships rarely have the firepower to destroy an attacker before the attacker can inflict significant damage, other than through use of missiles.

Getting this kind of data is the job of the sensop. However, many ships do not have someone to operate the sensors. In these situations, it behoves the pilot to analyse every significant sensor contact encountered while at some distance from port. Aside from breaking up the monotony of travel, this can provide early and perhaps the only warning of an incoming pirate. Likewise, do not assume that every ping of active sensors scanning your ship indicates hostile activity; they may be just as wary of you as you are of them. If the computer says they have a weapons lock, it is time to run if you still can.

DOGFIGHTING

Almost everyone has seen recreations of fighters executing dizzying manoeuvres around enemy capital ships, dashing in and out of turret fire that cannot keep up, while crippling the larger weapons that have no hope of coming to bear.

Not as many know that 100 and 200 ton ships are perfectly capable of this, should any much larger ship close in. Dogfighting is about relative size; while small ships may not be built for dogfighting, they can be more manoeuvrable than capital ships. Large ships, particularly military ships, will try to fire from long range precisely to avoid this. A dogfighting ship that can outmanoeuvre a larger ship effectively disables any weapon not mounted on a turret. This only works against single large ships, which is why capital ships fly with escorts. Additionally, it only protects the dogfighting ship while it is close, assuming it can dodge fire from

turrets. Even with these countermeasures, dogfighting can still be useful to buy time, potentially enough to dock and board; assaulting a cruiser full of marines is easier than trying to survive point blank shots from a spinal mount weapon, although only barely.

BOARDING ACTIONS

Boarding a ship is generally done only for one of two reasons – to capture the ship or something on the ship.

Taking things on a ship is the mainstay of pirates and slavers. Pirates usually will allow a crew to survive and limp back to port, perhaps to soothe their losses with insurance. Some pirate operations amount to elaborate insurance scams. Slavers who do not seize the ship will leave enough crew on board to manoeuvre the ship home, often only taking passengers or skilled but nonessential personnel such as medics. Their objective either way is to board the ship, obtain their loot and leave quickly.

Those who wish to seize a ship are a different matter. Their objective is to board then take over the vital control areas, generally engineering and the bridge, from where they can lock down the rest of the vessel and snuff out any remaining resistance. Many are willing to release passengers and any crew who do not fight back. However, enough cases of raiders taking everyone as slaves make many crews fight back to the last.

Boarders must first gain access to a ship. Unless the crew can be talked into shutting down their engines, this requires either a very fast boarding vessel, ion weaponry or severely damaging the ship. The latter risks damaging or destroying whatever the boarders came for and only the most novice pirates do this. Unfortunately, piracy is an occupation with high enough turnover that there are always plenty of novices.

Once boarders have access, the defenders have limited options. Repelling boarding only means the pirates are free to try again. Convincing the boarders to give up, exhausting their personnel, or counterboarding are the most viable options. The latter two are similar, as they both involve taking out most or all of the boarding crew, the difference being whether this is done on the target ship or on the boarding ship.

A small ship will face two common boarding situations. First, custom officers present to obtain information that, assuming there is no contraband, costs the crew nothing but time. Second is when being threatened by pirates, where it makes sense to dump cargo overboard if one cannot outrun, evade or otherwise escape them. It saves time and reduces risk for both sides, so many pirates accept this measure even if there is a chance the target ship is withholding the most valuable goods.

When exceptions are encountered or if contraband is aboard, a true boarding action will follow. Typically, boarders will attempt to access the bridge and engineering spaces while defeating the target's security systems. It is sometimes possible to bypass security if an attacker is familiar with the nature of a target's procedures. Even in the Third Imperium, this is not always the case; what is popular around Capital can be wildly different from Terra or Regina, and current practices at all three can vary greatly from what was popular a century ago.

In an emergency, such as if the bridge is disabled, the ship can be operated from any engineering console. Some ships refer to this as an 'emergency helm' or 'emergency bridge'. The most common use is to directly operate the power plant and manoeuvre drive, in an attempt to move the ship somewhere to fix enough to restore bridge control. Normally, systems are programmed so bridge consoles will override engineering consoles, which may surprise those who think that engineering would have priority. Disabling the drives is possible regardless of the bridge's wishes, as that falls under emergency shutdown procedures.

MUTINY

A mutiny is a special type of boarding action. While ships have safeguards to minimise risk, small ships can only take so many steps as crew need to be able to perform their jobs. The best defence a captain has against a

BEING BOARDED

If your ship is being boarded by anyone other than slavers and you are a passenger or otherwise not expected to defend the ship, take shelter wherever you are, only moving if someone tells you to. If the boarders are not here for you and you are no threat to them, their jobs are easier and your life will be longer.

mutiny is to ensure the crew never has cause to do so. Ensure they are kept informed of decisions and the reasoning behind those decisions, have opportunities to vent grievances regularly, give the option to leave at ports of call and make sure those who file complaints know someone is addressing their issues.

Justifiable mutinies follow a generally accepted set of rules. Those who are thinking of mutiny should read this subsection first and weigh the consequences. Unless the situation is urgent, it is better to discuss the issue civilly or wait until port and leave the ship.

There must be just cause, generally either intentional breach of contract or a major Imperial law. Mutiny over a traffic ticket is not acceptable, mutiny due to the captain failing to distribute pay for the past month and not letting crew disembark at ports is. Slavery, murder, maiming, hostage-taking or conclusive evidence of intent to do so can constitute just cause.

The mutiny must use proportionate means and not cause more harm than it would prevent. Falling a month behind on payroll does not warrant shooting the captain. It is better to inform the authorities at the next port, who may be able to help, possibly even award the ship or a portion of the cargo to the crew depending on circumstances. It is easier to fix back pay while in port than mid-jump. Likewise, crashing a ship to prevent delivery of cargo does not help solve this issue, although crashing a ship to prevent deployment of nuclear weapons against populations can be justified.

The crew must turn the ship over to a legitimate authority such as a starport's security team as soon as is practicable. Turning over the ship after a month of trading on the owner's dime is not 'as soon as is practicable'.

Finally, the crew must accept whatever judgement authorities provide. This is often a sticking point with many; just because a crew took over a ship does not mean it is now theirs.

ORTILLERY

Ortillery, from 'orbital artillery', refers to the practice of bombarding targets on a world with ship weapons from orbit.

In many cases, the target has no means of firing back, rendering this a simple act of demolition. While energy weapons lose power when firing through an atmosphere, their unlimited ammunition means the bombarding ship can park high above the target and take its time razing it if there is no effective opposition, for as long as power plant fuel remains. Given enough time, a single turret laser could eventually turn a city to craters and slag, save vaults, armoured, or other particularly tough areas. While typical ship sensors can find sophonts in the open at this range it can be difficult to find those hiding indoors. Since killing everyone in an area is the usual reason a small ship would engage in ortillery, thorough demolition of any structures at the target location is often called for. If desiring immediate destruction, most prefer slugthrowers or missiles, although this is rare outside of military operations.

For the most part, this is something a small ship should never do if the world has any population, which is usually a prerequisite for having something worth attacking. While a captain and crew may consider an undeveloped world to have no way of immediately retaliating, one of the first things most starports build is the ability to deflect asteroids from hitting the planet, typically by blowing them into tiny chunks or vaporising them enough to alter their course. This firepower is more than enough to retaliate against a small ship that chooses bombardment from orbit.

If done in the Third Imperium, a lone ship declaring war against a populated world is usually in contravention of the Imperial Rules of War, meaning any Imperial Navy ship now views it as an enemy combatant. Causing the Third Imperium to declare war upon one's ship and oneself rarely amounts to anything more than a particularly determined method of suicide. It rarely even gets much mention in the news, beyond reports of the atrocity that started the affair. It is certainly not an honourable way to go.

Dictators who run their worlds by paying passing starships to 'rough up' villages where dissidents gather are often more trouble than the Credits are worth. Whether large like the Third Imperium or smaller like the Julian Protectorate, if this is in or near any functioning interstellar polity, it is probable that the polity intends to remove that dictator before too long. Removal often has negative consequences, generally execution, for anyone who recently helped said dictator harm their people.

AMENITIES

While some ships provide the bare necessities, many ship captains realise the importance of amenities to keep morale high through the endless voids of space. The old joke that 'the thrashings will continue until morale improves' proves resoundingly false. Some try to implement that system only for it to inevitably backfire, making their crew less effective. A crew's morale improves when they have items aboard that make their life easier both on and off duty, resulting in better performance. While most of these options do not come standard, shipyards can implement them if there is room aboard the ship and enough Credits set aside.

WORKSTATION ERGONOMICS

A wide variety of workstations are available on ships where the operator stands, sits or is strapped into a harness within reach of controls. Something as simple as moving a commonly used control button closer to the operator's seat can help improve efficiency and morale. Making sure a conduit has a sturdy ladder to descend to the master cut-off switch also falls under this category. For workstations that require the operator to stand, the consensus is to assign either comfortable shoes or decking pads to minimise fatigue. Making sure all items in the armoury are properly organised makes inventory and maintenance easier, and helps crew find items quickly when under attack.

STATEROOM OPTIONS

A stateroom is a crew's home aboard ship. While many captains and starship owners only take the crew's working comfort into account, their time off is just as important. While some crew employ vast amounts of creativity to maximise available space, others only need a small vase with flowers to consider their room peaceful. The contents of a stateroom depend on the needs of whoever resides within it.

STANDARD COMPONENTS

A standard stateroom will have, at a minimum, a bed, access to a fresher and life support for two sophonts, even if designed for single occupancy. Everything else is optional and varies from ship to ship.

The bed will most often be a bunk bed, potentially built into a wall. Rooms occupied by a pair of sophonts who wish to share their bed commonly see the upper bunk dismounted and placed alongside the lower bunk, or sometimes just replaced with a larger bed, shifting storage into the space the upper bunk used to occupy. The fresher is in an enclosed or partitioned area, either attached to and only accessible from the stateroom or right outside. Some layouts that use the 'right outside' option share freshers among staterooms to save space. On these ships, any high or luxury stateroom has its own fresher.

Other options include a storage space such as a closet, cabinet and/or shelves. A chair and desk with wall-mounted monitors that can access the ship's computer is common. Mini-kitchens are a frequent choice, often installed as default, but these rarely consist of more than a countertop, microwave and water dispenser, sometimes in folding units stowed overhead when not in use.

Some crew spend all their non-working hours in their stateroom, while others only use it for sleep. The degree of personalisation can indicate how long someone has been aboard or expects to be aboard. Many crew members personalise their room immediately while others used to constantly changing staterooms or ships may never unpack, no matter how long their stay.

HIGH OR LUXURY COMPONENTS

Standard staterooms are often plainly furnished with only basic decorations. High and luxury staterooms have many themes available from the shipyard, from antique seafaring wooden planks lining the walls to holographic projections that make the room seem bigger.

While the three ships outlined in the Ship Walkthrough chapter come with standard staterooms, many ship owners take unused staterooms and combine them into high or luxury staterooms. On top of the increase in size, there are quality upgrades to components and capabilities of the room. Environmental systems have better air filtration, the mini-kitchen is expanded, the bed's softness is adjustable and the room typically has a theme that ties colours and materials together

for a pleasing atmosphere. For some packages, expanding the shower to fit two sophonts makes it less claustrophobic and more inviting. Communal showers fitting more than two at a time are rare, particularly on small ships. Certain other upgrades do not actually enlarge the stateroom but devote extra space to support machinery or storage for deployable fittings, such as a bed that takes much of the room when folded out but folds away into a closet one quarter as large.

On occasion, luxury staterooms may be more extensively customised, such as by installing bushes and trees to make it look like a miniature forest or covering everything in water-resistant surfaces and setting the humidity on high. This requires advanced knowledge of who will be occupying the stateroom, as well as access to materials.

As they consume more space on a ship, shipyards more often build high and luxury staterooms for double occupancy. This is rarely a detriment for single occupants as they can sleep on one side of a bed made for two and either ignore the second desk or offer its seat to guests. Shipyards may install options found in common areas in the most luxurious of staterooms, depending on space needed and the occupants' tastes.

MINI-KITCHEN

The standard stateroom comes with a mini-kitchen built into the wall that contains a small oven, a fold out shelf used as a table and a filtered water dispenser. Designed for pre-packaged rations, it can be utilised by cooks who do not have the luxury of a common area with galley or prefer to fix their own food. The crew brings food from the galley or cargo bay and either reheats it in the oven or serves it at storage temperature. Crew who enjoy cold snacks will invariably find the shortest practical route from storage to stateroom.

In high or luxury staterooms, dining option upgrades are usually the most visible changes. It is common to add a desk or full table and chairs, along with a larger and more noticeable oven. Some captains and crew who prefer to do all their work from inside their stateroom opt for expansive upgrades, such as installing refrigeration devices and food storage. Stewards will typically refill passenger stateroom food storage.

FRESHERS

Most sophonts are familiar with the concept of freshers from a very young age. Standard freshers have all the necessary items including a waste collection unit, washing station and shower for keeping the user clean. While designers fashioned the fresher around human

parameters, it is adjustable to fit sophonts of similar size and structure to Humaniti. Ships built by cultures outside the Imperium will have freshers made to their own standards.

The waste collection unit provides an adjustable support area to help sit or stand comfortably, then gets rid of the waste in a safe and hygienic way. Above the waste collection unit, the fold down washing station utilises ultrasonic waves and air to quickly wash and dry extremities. The Imperial standard is to be adjustable to accommodate paws, tentacles and larger or smaller hands.

A sonic shower concentrates on using ultrasonic waves and air to clean whatever is inside. As with the smaller wash stations, some versions use water or steam instead. Versions aside, one need only step into the area and the shower will wash and dry automatically within five minutes. Similar to decontamination chambers, doctors may add additional airborne antibacterial agents to the regular wash if needed. Likewise, these chambers can be set to report to the ship's medic the extracted material analysis, although only on a general analytical level.

PASSENGER STATEROOMS

Non-crew staterooms are normally devoted to paying passengers. Although some crew will concentrate on their own staterooms first, allowing staterooms meant

PASSENGER-BROKERS

Some luxury staterooms have extra-wide doors. Despite the common joke, this is not primarily to cater to obese passengers. Rather, it is to permit passage of larger cargo containers. Some bring more than a full displacement ton, accepting cramped conditions in their luxury stateroom in order to ship more cargo for the same cost and time. This is technically in violation of the passage contract but usually ignored, as it causes no problems so long as the extra cargo fits within the stateroom and through passageways, while such passengers rarely place the extreme demands on the stewards. Lesser levels of passengers should expect fees for or refusal to carry excess baggage and even those willing to pay luxury rates should ask the ship's captain rather than assume this will be allowed.

In many areas, high society looks down on passenger-brokers, occasionally leading to unpleasant confrontations if passenger-brokers and other high passengers are on the same ship. To avoid this, some passenger liners will only take one type or the other on any given trip. As a courtesy and out of caution, ships that take both passenger-brokers and speculative cargo at the same time traditionally avoid taking the same type of cargo as their passengers, except with permission of those passengers.

for passengers to slip their minds, these need attention to make sure the stateroom has everything the sophont wants as well as keeping them occupied and happy. A typical experience is of a tastefully decorated room, the floor space empty aside from furniture. A passage purchase grants a limited amount of cargo space allotment and while some ships arrange this as large closets attached to passenger staterooms most allocate part of the cargo hold. The former affords more privacy while the latter facilitates handling of larger cargo, particularly useful for 'passenger-brokers' who purchase high passage to bring along a ton of trade goods for sale at the destination, intending to earn a profit substantially higher than the price of passage.

Guest quarter decoration often focuses on painting the walls, as well as providing small trinkets and pieces of art to make the room seem friendlier.

Quality depends on the clientele the ship wishes to transport. There are ships devoted to luxury transportation of passengers but small size ships typically focus on poorer clientele as they usually lack amenities to keep richer guests entertained. This is why ships such as the *Empress Marava* carry low berths, hauling the poorest sophonts in stasis without having to add facilities to the ship. Many compare low berths to shipping human cargo. As the saying goes, 'Cargo doesn't complain. Passengers do.'

PERSONAL PREFERENCE

As noted in the Life Support chapter, every stateroom has its own climate control for the occupant to adjust temperature and humidity. Some sophonts prefer to sleep in a cold room under blankets or in a hot room with a fan. When fans and blankets are not enough and the sophont requires more extreme changes, a ship can dedicate tonnage to extra environmental controls, even providing an airlock to transition between the rest of the ship and the modified stateroom. Each stateroom is self-contained as well, so crew who like high humidity can live in peace next to others who prefer a dry desert. A degree of sonic isolation is likewise standard, so a passenger whose room is adjacent to the power plant or drives might never know. High and luxury staterooms have even more controls, mostly for upgrades to basic furniture such as heated beds and chairs.

As many shipyards say, 'what they want in their stateroom, stays in their stateroom'. Becoming a mantra of sorts, a subculture of individuals samples amenities available across a number of ships in their quest for a perfect environment. While most sophonts have a variety of wants and needs, they mostly look for something that is relaxing and comfortable. The captain who fulfils this will have a happy and productive crew.

BRIDGE-STATEROOMS

Any ship design needs to minimise wasted space. There have been countless attempts to do away entirely with passageways, internal doors and other non-functional areas. The logical extreme, a vessel that is simply one large room, can be realised if the vessel will only open into breathable atmosphere, needs no internal privacy or containment and a few other factors that are not generally true for starships. Designers succeed with this design on some small craft and grav vehicles but privacy and operational concerns make the need for multiple rooms on a large ship evident.

For small ships, especially where the entire crew comprises only one or two sophonts with a high degree of trust, the generally agreed-upon practical minimum is five rooms, not counting ordinarily-crew-inaccessible spaces such as the fuel tank.

1. The airlock must be enclosed; otherwise, it will not function as an airlock.
2. The engineering section is best enclosed to contain smells, sounds, leaks and potential accidents.
3. Even on a single-crew ship, the fresher is best enclosed to contain smells and facilitate cleaning.
4. Enclosing the bridge is mainly done in case of video or holographic communication, to allow a professional background to be presented rather than showing a messy kitchen or bunk to employers and business contacts. Designers of ships with less professional intent sometimes do not separate the bridge from the sleeping area but frequently add a mission-specific room, such as a separate cargo hold.
5. This leaves sleeping, exercise, and food areas, which can be part of the same room. On most ships designed this way, the other four rooms connect only to this room. Sometimes the bridge or mission-specific room can be accessed directly from the airlock and some engineering spaces connect to the bridge but this area remains a central hub the rest of the ship is designed around.

While none of the three ships showcased in this book are that minimalistic, small ships laid out in this fashion do exist. Adding more capabilities, such as turrets, more crew, more cargo space and other items, adds the need for more enclosures.

COMMON AREA OPTIONS

The commons are a gathering place for the crew to interact while off duty. A good commons can satisfy their needs for socialisation, food and entertainment, thus keeping morale high. While common areas for each ship in a class start out identical, with features rarely changed or upgraded, they become a true reflection of the crew, unique to every ship. A tidy and spotless commons may signify a tidy steward or crew that use their time in pursuits other than socialising. A commons with many scrapes and dents on the walls may denote a rowdy crew, while assigned seating at the galley may be indicative of a strict officer system where crew only socialise with their own rank. Once the ship is in use, the commons absorb the crew's tastes, so to truly know a crew one must visit the commons while touring the ship.

While the possible amenities installed in a commons are vast, shipyards have templates for the most popular customisation options. Many were specified by ship or shipyard crews after the ship class was created, in some cases included in updated versions of the ship's starship engineering package. They typically fall under three categories and it is commonly believed that to best help the morale of crew and any passengers, a ship needs something from all three.

Food and drink is the first. A typical commons has the ability to make, heat, render safe and serve food and drink using standard cooling, heating and storage devices. Some galleys are so simple they only dispense rations to the crew without variation, although this tends to cause discontent. Gourmet kitchens cannot fulfil this need by themselves, as they require a knowledgeable steward. Many ships prefer to install an amenity that requires less skill to use; a wet bar, stocking the crew's favourite drinks and liquors. If supplies run low during a jump, a crew could benefit from adding a microbrewery and distillery. Some crews even take pride in their unique flavoured beers and wines, sharing them as a token of trust with others.

Entertainment is the next category. Of the three, it is the most frequent first upgrade for a ship, largely due to how easy entertainment options are to install and an advanced entertainment system to create VR gaming rooms is very popular. However, no matter the advances to virtual entertainment options, there remains demand for live action theatre. Larger ships, especially liners, may have professional live entertainers but smaller ships with theatres rely on the crew to be multi-talented. Many ship owners who are fans of this form of entertainment gladly give up the required space, whether the crew prefers it or not.

The third category is sometimes labelled 'training' or 'fitness' and generally deals with exercising or conditioning the mind or body. The most prevalent installation on smaller ships is a gym with exercise equipment, sometimes augmented with a hot tub or sauna. Another example, frequently seen on ships whose crews expect personal combat, is a gun range with holographic targets. Occasionally, theatres are set up with mannequins or robots to help crew practice melee combat forms.

Mental training falls within this category. While anyone can sit in their quarters and read, ships may install a dedicated library; some libraries devote space to hardcopy books, others to equipment to enhance reading and absorbing information, while still more use the space for a dedicated database with a truly

prodigious amount of reference documents. A few small ship crews use theatres as diplomatic training facilities with holographic simulations from a given culture, to study how best to interact with the people of a world.

UNCOMMON COMMONS

Ships without proper commons will see other areas put to the same uses within a few jumps; people need to eat somewhere, cleaning clothes and dishes happens at some location, and most sophonts express the desire to be social from time-to-time even if the particulars vary by culture.

However, substitute commons do not perform as well. This is evident in the *Suleiman* design, which has an office but no commons – so the office gets used as commons. Crews of these ships have a measurably higher average demand for shore leave. It should be noted that many 'offices', especially on small ships, are repurposed bridge space, providing the minimum space needed to have a private conversation.

PETS

Having an animal companion aboard can have results ranging from 'great for morale' to 'proximate cause of the ship's destruction'. While many crew find interesting animals on their journeys they would love to keep, not all can be domesticated as pets.

If the crew acquires a pet, give it the recommended medical treatments for shipboard life. In most cases this includes implanting a transponder to quickly find it. Checking this transponder must become part of the take-off checklist, alongside making sure all crew are aboard. The transponder can interface with door controls and it is typical to give pets open-upon-approach access to low-security doors but never to airlocks, so they cannot exit the ship unescorted. These treatments induce sterility; unexpected offspring can be a significant problem if discovered in port, let alone mid-jump. Likewise, even if having multiple pets allows them to play with each other, most small ships are ill suited to house more than two or three at a time.

The crew must tame and train a pet to act appropriately aboard ship. Specifically bred ship's cats are genetically disposed toward proper behaviour but this is not the case for all species. Wild animals are not tame and many have no capacity for training. Urination or defecation in the wrong place or chewing the wrong wire can disable a jump field mid-jump. A properly trained pet is no more likely to engage in excessively destructive behaviour than a non-feral sophont. However, even with proper training, expect a pet to bring minor chaos which, if managed properly, can improve morale.

Whatever pet the crew decides to have, it will need daily maintenance and upkeep to keep the pet healthy and happy. The most frequently overlooked issue with pets is that most have more restricted diets than most sophonts. While some animals adapt to a different diet over time, feeding a vegetarian pet meat can cause them to be very sick, likely all over the deck or crew quarters. Clean water or whatever hydration the pet requires is vital. Most pets can adapt easily to standard temperatures and air pressures, although some require aquarium tanks and controlled temperatures to be comfortable. While humans have adapted to climate controlled mobile vehicles, a large space is best for a pet to exercise and explore. That is why most ship crews prefer pets that can exercise themselves by wandering through the ship instead of having their own holding tank. These pets frequently become the ship's mascot.

EXERCISE AND SPORTS

Most small ships focus on one-on-one activities like board, card or video games to exercise the brain, while others adapt spare cargo or common area space to play games that require more room. This exercise is vital not only for morale but also to maintain the crew's physical and mental agility. Temperance is vital, as the crew should not feel forced to participate in activities but not giving them places to exercise both mind and body will cause harm.

Another type of ship activity to keep the crew's reflexes sharp during jumps is a variant of laser tag or paintball in a portion of the ship. The crew should never designate the bridge and engineering areas for this; cargo holds and extensive commons are much better. Ammunition for this varies between foam, ink and low-powered lasers that interact with electronic sensors worn by the players. This game typically divides the crew into two opposing teams, although free-for-all fights can work. Studies have shown that crews who engage in this activity know the interior of their ship better and can use it to repel intruders more easily. When all or most of those aboard participate, the play area sometimes includes corridors, with spectators remaining in out-of-play areas such as staterooms.

VR GAMES AND THEMES

Virtual reality can help keep crew and passengers entertained at a fraction of the cost of refitting the ship. While most ships are not equipped with VR software, a passenger or crew can easily bring their own aboard. A typical starship has enough computing power to run the most popular VR games available and terminals located in staterooms and workstations can link to standard ports on a variety of headsets and wafer jacks to escape from reality or challenge the mind.

If in the mood for something more relaxing, some of the cheapest VR software uses audio and visual themes to help find a perfect relaxation spot, perhaps on a popular beach listening to the waves or a snowy tundra under an aurora. Naturistic sounds such as those from a sophont's homeworld can help calm and relax, assisting in better work or sleep. Some first time users report difficulty getting used to wearing a headset while sleeping, so sophonts wishing to start this practice are advised to start for a day or two when they can afford poor sleep, although this can be sidestepped by those with wafer jacks or neural links.

While single player VR games are far more common, there are multiplayer games that can be played from one's stateroom by linking to a participating world's 'shard', a set of servers that players log onto, albeit limited by communication lag time. Players on a moon might have a two second round trip lightspeed lag communicating with a shard on the world, making them unable to participate in events that require sub-second reactions, so a moon and its world would receive their own shards. Some ships promote bonding by running group exploration-type VR games during jumps.

Many ship captains who seek out VR games do so for educational or training capabilities. Training for military manoeuvres or learning a new language is easily accomplished with the right software, although purchases of advanced software with primarily military applications are monitored by the Imperium. Cultural simulations that a diplomat or broker might use to familiarise themselves with a destination world are less monitored, although these can see military use in planning psychological operations. While it may take shopping at a few starports to obtain the VR software needed, it is worth it to keep the crew trained, informed and relaxed during a voyage.

CREW ROLES

Many consider a ship's crew one of its most important systems. There are many guides, most written from the perspective of large and/or military ship crews, covering standard positions. This chapter exists to inform the reader about things often left out of said guides which matter to small ship crews.

THE DIVISION OF LABOUR

Anyone who has spent much time aboard a starship is familiar with crew dividing labour, each person having certain tasks. It may only take one person to pilot even the largest of ships but they will not have a ship to pilot for long if the engineer ignores instabilities in the manoeuvre drive or does not supervise the power plant. On small ships, these and other critical tasks take little enough effort that the pilot can do them while piloting. How big a ship can be before it becomes 'large' is a matter of when this becomes impractical. There is quite a difference between two people operating a 200 ton ship and the double digit crew of a 2,000 ton ship, even if both are regarded as 'small' by a member of the thousand-strong crew of a 200,000 ton ship.

Some crew roles are vital to almost all ships. Some only matter on certain types of spacecraft, such as astrogation which is rarely employed outside of jump-capable ships. Other roles depend on the size of the vessel; a full time steward is normally only needed for ships that have enough passengers, which implies the ship is large enough to carry that many people. However, the crew needs to perform all roles aboard a ship to keep it running and the smaller the ship's crew, the more tasks fall outside someone's official job description.

Those who prefer to do only one job are better suited for work on large starships. Small starships offer exciting, fast-paced tasks with a wide variety, for better or worse. The statement 'it's not my job' is not often heard on a small starship, as the crew understands the need to help out with more than the tasks covered by their job description. Although there can be room for focus on single jobs, particularly for junior members in crews of at least three, the term 'omnidisciplinary' is applied to individuals who have shown themselves to be excellent small ship crew.

For example, a typical day aboard a *Suleiman* with one crew member aboard may start with waking up when the ship exits jumpspace, then setting coordinates to a nearby planet. While the ship autopilots, they will repair a jammed food dispenser and make up the spare stateroom for guests. They then may need to coordinate with local traffic control, land the ship, conduct trade and diplomacy negotiations, load cargo and pick up passengers. They will need to take off again, entertain passengers and help them settle in as the ship autopilots to a safe jump distance, before doing astrogation calculations and guiding the ship back into jumpspace.

Crew used to working on a large starship may find the transition to a smaller vessel unsettling. The lack of work significantly reduces their main role but others may ask them to do things they have never done before, leading to confusion. Some small ship captains refuse to hire those from large ships for this reason. While small ships are not for everyone, some enjoy the thrill of never knowing precisely what they need to do, building a sense of pride that comes from knowing everything about their ship.

CREW REGULATIONS AND AUTOMATED CREW

The Imperium created standard crew regulations with large ships in mind. This is less formal legislation and more what hiring halls prefer, most large employers offer and most crew expect. The reality that most ships are small ships where these regulations are inappropriate forced a number of concessions.

Where there are standard pay rates for standardised jobs, officially one crew may perform two jobs and receive 75% of the standard pay for each. Assuming the person is up to doing both, they both have less things to do and earn more money, whilst the captain has one less person to manage and saves a bit on life support. Due to multiple studies on overworking, no sophont is supposed to be paid for performing three or more jobs. When this happens, it is usually on small crews that do not care much about regulations; a ship's pilot, astrogator and engineer are highly unlikely to walk out on the captain when all four are the same person. Many small ships pay their crew with shares of the ship's profits rather than standardised salaries. Some

reserve this for their 'core' crew who go on adventures beyond their jobs, while other crew expected to perform only their jobs receive standard salaries but are free to come and go at port.

Even for ships operated entirely by individuals, crew role lists still commonly exist. This is why the *Suleiman* listing in this book shows pilot, astrogator and engineer roles, despite the fact that having three separate individuals performing those duties is by no means common.

Some say this is a more meaningful distinction between 'large ships' and 'small ships', although others believe it less useful for classification since it can change from ship to ship, and between captains on the same ship. Does the crew have an astrogator or someone with other duties who performs astrogation as needed? If the ship is armed, does the crew have one or more gunners or just people with other duties who operate the guns as needed?

This division informs the use of automated crew – see Drones and Virtual Crew on page 64. Large ships replace certain roles with software or robots capable of performing the job, viewing it as an investment with payoff in the formula (price of robot) / ((replaced crew's monthly salary and life support cost) – (monthly maintenance cost of robot)). Small ships have a harder time with this, as the captain must replace each person performing multiple roles with a combination of software and robots; an engineering robot may be less capable of cooking a meal or keeping an eye on the sensors compared to a person trained as an engineer.

Automated crew found on small ships fall into one of three scenarios:

- First is the rich loner captain who does not want a sophont crew.
- Second amounts to an automated troop transport, carrying a team of sophonts that must be able to adapt to conditions encountered on the ground with the space portion of the trip not expected to present danger or difficulty. The missions assigned to this team often involve some degree of secrecy, so they use automation to reduce the number of sophonts that must keep the secret.
- Third and most common is when a small ship crew comes into possession of a much larger ship but is not comfortable switching to large ship procedures. Filling positions with robots allows the remaining crew to continue using small ship crew procedures.

SHIP'S ARTICLES

Ship's articles are documents that serve as a ship's constitution or charter. These set up the responsibilities of a ship's captain and crew in an easily accessible format. They are less common among smaller ship crews, who often see them as an unnecessary formality. Captains use them to stop arguments about pay, watch structures or codes of conduct long before they start, and they also clearly lay out a captain's authority to maintain discipline, including what punishments may be issued as procedures to record crew complaints and disciplinary actions.

Most articles start as copies of larger ships' articles or boilerplate materials but are modified over time as larger ships can often afford to turn away crew who do not agree with aspects of the ship's articles but smaller vessels may not have this luxury. On these ships, hiring crew can involve minor changes to which all crew must agree and hiring crew is often done as a collective effort on smaller ships. Articles aboard larger ships are more set in stone, written in dense legalese; attempting to hide objectionable aspects of a ship's working environment from prospective crew is usually the remit of ships belonging to large corporations, not least because attempting this without the backing of security or military forces is profoundly unwise.

Ironically, this results in some pirate ships having excellent crew conditions; irritating those who have already demonstrated wilful disregard for the law decreases one's life expectancy. There are recommended practices for those who wish to remain on the right side of the law and avoid underhanded tactics. Under no circumstances start work on a ship without a contract, ideally written in plain language and checked with a lawyer. The contract must give the basic wages of all crew positions, as well as specifying which are only on duty for certain shifts and what conditions can require off-shift duty. It should also clearly lay out the expected duration of contract and conditions for termination. Any changes to the contractual period must be by mutual consent only. Requests for termination should have enough notice for the ship to reach the next major port where it can get replacement crew.

PROFIT SHARING

A good rule of thumb for more comfortable employment, if one can find it, is to ask if the ship practises profit sharing – not to be confused with 'ship shares', which represent fractional ownership of a ship. Should a ship make more profit than expected, the excess is shared among the crew as well as the owners. As profit sharing can limit a corporation's

Suleiman

Gazelle

cash flow, this serves as a useful signifier that they are more willing to provide other concessions to the crew. Profit sharing gives every crew member a financial interest in making sure the ship runs effectively and thus as profitably as possible, which means backstabbing politics are kept to a minimum. Everyone has a motive to help out should someone run into unexpected difficulties.

Profit sharing is usually not motivated by benevolence and is simply a different approach to maximising the bottom line. Profit sharing is often proportional to crew members' duties; a galley attendant or cargo handler might only receive a quarter share while officers receive more than one, with the ship's owners still getting a larger share still. Corporations which engage in profit sharing often reason that crew motivation and morale will improve profits, increasing the corporation's share more than the amount they pay out.

That said, profit sharing is sometimes used by ships that do not have a reliable source of income and thus have to divvy up profits as they come in, in lieu of salaries. Those who cannot afford to miss a paycheck should not rely on profit sharing.

CREW SKILLS AND RATINGS

Ships associated with a government or military are crewed by government employees or service members. Megacorporations retain crew often educated in their own merchant academies. Smaller corporations and free traders generally recruit and hire crew from a variety of sources. In an attempt to prove that individuals are qualified for crew positions and quantify their level of skill, different organisations will endorse them with official ratings. This provides reassurance to a hiring captain that their new engineer is not a dilettante with delusions of grandeur who will melt down the power plant on their first day.

The Imperial Army, Marines and Navy provide certificates giving such ratings at discharge, based on formal training received in the service. The IISS maintains its own system using peer-reviewed exams. Notably, scouts will rate one of their members on a skill even if the member never sat for formal training but 'picked up' sufficient knowledge along the way.

Megacorporations provide certifications to employees trained by them who leave their service under good terms. Aslan clans maintain similar policies for those who served the clan, provided their service was honourable, although acceptance of these varies outside of Hierate space. Local accredited colleges often provide ratings along with a diploma. While good colleges routinely distribute records to nearby systems, the validity of a recent accreditation in another system can be unreliable. Use caution with any 'school' that promises to provide an official skill-rating certificate in exchange for a large fee.

The Sishekarek is the ancient Vilani traders' guild that has certified starship positions for 6,000 years and their ratings are highly respected in areas that maintain a strong Vilani culture. In Vland, it is virtually required for employment on a starship. Their testing centres can be found in Class A and most Class B starports throughout the Imperium, as well as some a short distance beyond

its borders. Vilani megacorporations rate all their ship crew through the Sishekarek but the guild will certify any skilled individual who passes an exam and pays a nominal fee, typically Cr300–800 depending on the position. This provides an opportunity for individuals who came by their ship skills in an informal or illicit manner to receive an official rating.

Small ship captains will find qualification records useful to check but may not trust them wholeheartedly. It is uncommon but possible to forge qualifications, especially when the legitimate record issuer is half a sector away. More than one captain has signed on a crewmember with a spotless record, only for them to fail abjectly and leave after a single jump, willingly or forcibly. While large ships can absorb these losses, a free trader would rather not lose their only engineer as a fraud after committing to a jump to a backwater world where a replacement may be hard to find. Less common are those who wish to learn from experience rather than schooling and believe that life among the stars is easy. Some may think that just memorising this book is sufficient to become a star trader.

Crew looking for work should be honest about skillsets and goals; apply for a working passage as an apprentice instead. Apprentices will learn far more under an experienced crew and have fewer major responsibilities. The pay will be minimal but there is less chance of winding up penniless in a strange system or condemning an innocent crew to death by misjump. Many crew, even some captains, got their start in space this way.

The wise captain will be sure to place any new crew through a simulation to test competence under normal operating conditions. Running through the most common procedures can take under an hour and will give the captain a much better idea of the new hire's strengths. Asking basic questions during a job interview is a good idea; if an alleged engineer does not know which component stores power for jump in a jump drive, they are probably not competent to act as the ship's sole engineer. A good captain knows the fundamentals of every role on the ship but someone who obtained a ship without this experience and needs a crew quickly may be able to ask questions based on the relevant sections of this book.

THE PHANTOM POSITIONS

People familiar with crew positions on media about large and/or military ships often notice the distinct absence of two of these positions on small ships; the sensor operator (sensop) and communications operator (commo). Some crew view these positions as 'busywork', tasks assigned to low-performing crew to make them feel valuable. Commo somewhat earns this reputation, sensop less so.

COMMOS

On non-military ships, the ship's computer typically handles communications but a captain can assign someone to this task. This person rarely has anything to do but open and close a single communication channel on command. Captains assigning this duty should be aware of this and not assign crew who are mischievous when bored. Most do not recommend assigning this role as a punishment as it often results in consequences that amount to lesser forms of sabotage. Commos are more often present on ships travelling to regions where the typical population does not speak Vilani and Galanglic. While computer-based translators are standard for these situations, having someone who speaks the local language can help avoid faux pas that a machine translation may stumble into. A hybrid approach, having a crew who can swap language libraries as needed, is common among augmented crew.

In theory, commos also aid in communicating at very long ranges, clearing up weak signals and punching through jamming. However, outside of military missions, the solution to these issues tend to be either 'move closer' or 'they are distorting a fake distress call, which means this is a trap'.

SENSOPS

On military vessels, sensor operators are invaluable. From electronic warfare shielding their ship from oncoming missile salvos to watching for would-be ambushers, they are the eyes and ears of any armada and can easily be the difference between victory and defeat.

Most other ships concern themselves with getting from point A to point B. Rather than oncoming missile salvos, they care about predictable trajectories of oncoming planetoids or how best to weave through the constellation of ships near a starport. In these roles, sensor operation is a solved problem, managed by the automated systems that come standard with any spacecraft. Many believe the sensop is simply not required, relegated to the same obsolescence as coal stokers, powder monkeys or any other ancient obsolete job; software engineers program the computer for any expected circumstances or contingencies.

This argument may even hold water, right up until unexpected circumstances occur.

No matter how sophisticated, software cannot deal with circumstances the creators did not design it to handle. Automated systems may dismiss an anomaly that a sensop would realise is an approaching meteor storm. Handling these is a job best left to something that can react to them.

Computers are fast and generally non-discriminatory. A computer monitoring a sensor feed will never miss anything the sensors detect. However, a major part of a sensop's job is filtering this flood into a trickle of information. The ship's pilot may need to know about close objects and potential collisions but when landing on a world or making a pass through a ring system, an endless stream of proximity alert warnings and collision alerts is not conducive to maintaining an alert watch. The sensop is the command crew's last line of defence, filtering everything the computer detects for usable information, usually done through adjusting the software's assessment criteria with the sensop's judgement of what is important. The sensop will need to adjust the computer back to a default mode once the unexpected passes.

On some ships, the sensop will serve as the chief computer technician, working in close conjunction with the ship's engineers to fix problems, maintain the sensors themselves and ensure proper read-outs from monitoring systems. This steers them towards monitoring the computer for attempted attacks. Missile attacks have similar concerns, as the sensop conducts electronic warfare to spoof and divert the missiles.

'EVERYONE' DUTIES

On small ships, some roles that need no specialised training are shared by the crew, whether explicitly or implicitly. The captain may not assign them formally and separately, particularly where they do not pay specific crew for these positions, but they must be completed anyway.

Security is the most common of these. Every sophont has working senses, with which they can monitor their immediate surroundings. They can report evident threats, whether or not they are equipped and trained to fight. Most sophonts can throw a punch or claw if they have to, while few hostile boarders will pass on capturing or killing a crewmember because they do not put up a fight. Non-combat aspects of security include not letting outside parties access to the ship's computer and keeping information hidden from prying eyes.

Cargo handling is the next most common. Every sophont, with or without assistive technology, is able to move and carry a load. When at port, many vital ship functions temporarily become unnecessary. The ship can usually use the port's air and life support, many systems are powered down and sensors are rarely useful, which leaves many crew with no other duties. Unloading or loading cargo and seeing off departing passengers or finding new ones are tasks that most merchant captains would prefer to be done quickly.

The only duty that absolutely cannot be shared is that of a ship's captain, if only because ports list just one person in that role on documents, even for crews that try a more democratic approach.

STEWARDS

The steward rounds out commonly distributed tasks. While cooking, cleaning and tending to the morale of passengers is a well-recognised job, many crews never consider that the crew also requires these, especially those that do not take passengers. Some crews pass around cooking and cleaning duties, while others let them fall to those happiest to do them. No small number of crews, with no naturally talented stewards among them, rely on pre-packaged foods. Reluctantly and only when they can no longer deny the need, they hire cleaners while at port, frequently combined with maintenance. These crews often struggle with morale, the captain trying various styles of leadership to inspire the crew but not actually dealing with interpersonal problems.

If a ship will be carrying passengers, sufficient stewards are vital. Failing to meet this requirement can cause disaster, yet many overlook or brush it off due to having no 'hard' duties. A steward's duties are many:

- Advertise for passengers. Others can do this but advertising passenger berths takes more than just posting a note on the starport's datanet. At minimum, they obtain and post reviews from previous passengers. On a low TL world, this may include using billboards but at higher TLs this may mean renting advertising space or buying media ads.
- Accept payment. A good steward checks for counterfeit currency, makes certain any local transport taxes are covered by the passenger fee rather than coming out of the ship's share and ensures all checks clear prior to departure. This is easy on high TL worlds, possibly painful in low TL systems.
- Perform initial security checks of passengers. A good steward is the difference between an uneventful jump and a passenger pulling out a snub pistol on a tour of the bridge. A great steward will manage to do this without alienating anyone, preventing walkouts and keeping the staterooms full.

- Arrange special accommodations for passengers. Passengers with unannounced pets or food allergies are potential disasters for the crew. A passenger able to entertain others in jump or a couple who wish to share a room are opportunities that a good steward will catch early and make necessary adjustments for.
- Luggage handling. Someone has to bring the luggage on board and check it for concealed weapons. Other crew will often do the former and skip the latter. Stewards will sort luggage to the correct stateroom and control access to checked luggage while underway. This requires knowing which bags passengers can access and which suitcase has the handgun stuffed in it that should stay locked until disembarkation.
- Room service. This is not optional, as nothing scares passengers away faster than a room with an unmade bed. Multiplying this by the number of passenger rooms on a trader makes for a decent workload to handle, so stewards will often draft other crew to help.
- Entertain passengers. The average jump is 168 hours, during which passengers are locked in a metal box. A good steward will set up tours, use talented passengers to lecture or entertain others, run multiplayer game tournaments, start movie nights and more. This is an essential duty on a passenger ship.
- Feed passengers and indulge high passengers. This is essential unless the intention is to live out of meal packages. Passengers are less willing to accept this, although a masterful steward can sell them on 'spacer cuisine'. Different worlds have different ingredients available, save for common staples, which vary between sectors.
- The first line of security. An average trading vessel can have 10 or more passengers, any of whom might plot to take over the ship. A good steward herds them all, keeping injuries, scuffles and hijack attempts away. A great steward does it so well the passengers do not notice.
- Be the passengers' counsellor. While computers can help, they are self-administered and require the passenger to realise they have an issue. Stewards are sophonts. They can recognise issues that a machine will never see and refer the passenger to said software.
- Handle complaints. A good steward knows how to apologise, make amends and how to stall, cover, deflect, spin and outright lie away that which cannot be solved.
- Procure tips. Not everyone tips but people who particularly enjoy their trip may. A few hundred Credits per passenger is nice pocket change. High passengers may tip more and receive extra benefits during the journey.

Other ship-usage-dependent positions are more amenable to being done part time, which is why they are not often listed save on the most function-dedicated ships. An *Empress Marava* might or might not have one of the crew acting as the ship's broker. Steward, if listed, is a full time role if running a passenger service.

SPECIALISED BUT SHARED

Other roles also require specialised training and yet are so infrequently performed on small ships that they cannot justify being someone's primary job.

Many people immediately think of the astrogator. They calculate the route from star to star, setting up parameters for each jump. They help with navigation in-system but that is usually a decidedly simpler proposition. While they can focus on this when far from jump, even some large ships reduce astrogation to a duty performed by other crewmembers, particularly science ships likely to have someone with relevant training. Other ships have an 'astrogator' who is a general-duties crew member, using the title to cover for other functions they either do not have a good title for or, more often, do not wish to permanently assign a crewmember to.

Gunners suffer from the same problem. Their function in combat is clear but even the most frequently fighting ship spends far less than half its time at combat readiness, let alone actually fighting. Even in combat, if the enemy targets and destroys their weapon and they survive, they are usually reassigned to damage control or security. Outside of combat, they train and help with weapon maintenance but there is a limit to how much time can be spent on those tasks. As with sensops, dedicating crew as full-time gunners for an eventuality that might never happen is simply unaffordable. Designating who has gunner duty if attacked is vital, both to make sure everyone knows who has to reach the guns and to ensure the gunners are familiar with their stations. Beyond that, being a gunner might carry no consequence for a shipboard career other than a pay adjustment for performing two roles. There are quite a few 'gunners' on ships plying safe routes who took one course long ago and volunteer to for the extra pay.

The lack of enough dedicated mechanics and engineers is a defining characteristic of small ships. Someone has to perform maintenance, route power to ship systems, monitor the manoeuvre and jump drive, and make sure life support is not going awry. On a small ship with standard automation, the work this takes can be too small to need a full-time person. Even on ships that officially rate two or more engineers, it is common for them to have another role, usually an occasional-duty job such as gunner so they can spend most of their time in engineering. This can cause problems in stressful situations where they need to perform both duties, leaving no one to keep damage to the power plant or other systems from cascading into further complications. If a ship's engineers are performing other jobs as well, make sure they are unlikely to need to split their attention.

Medics appearing on this list may surprise and concern some but it is a consequence of the maths. One medic with proper equipment can tend to the routine needs of a much larger group than a typical small ship crew. Even without a dedicated medical bay, a small ship's demand comes to less than one full-time medic. Instead, many small ships have someone with medical knowledge among their crew rather than a specialist – or go without. The main practical problem is the medic's limited ability for self-care, most commonly solved by the medic having checkups at port. Some captains have their entire crew take a basic first aid course, much like they may have everyone take a basics of starship engineering course, although this can aggrieve qualified medics and engineers.

Administration is part of a captain's duties if there is not enough workload to justify a dedicated administrator. On small ships, this is usually a matter of record keeping and contract writing, simple skills adequately performed with informal training, especially with the vast library of free forms and 'boilerplate' templates available. There is nothing inherently binding this function to the captain; a small ship crew where the pilot studied bookkeeping might see them perform administration duties instead. Whoever does administration often acts as a quartermaster, keeping track of finances and goods. On ships where the administrator pays the crew in shares of the ship's profits, it is this person's task to keep track of what those profits are, so this person must be trusted not to embezzle.

SUPERCARGO

'Supercargo' refers to crew who have little or no function when the ship is away from port. **Brokers** are perhaps the most famous example, constantly busy making deals when a ship is in port but the moment the ship lifts off, they may as well visit the low berths to stave off boredom. Supercargo roles tend to pass the time in one of three ways.

First, many find ways to do parts of their job while away from ports. Brokers might study information on surrounding systems to help decide their next port of call or brush up on customs rules that will help them trade at their next destination. Scientific crews analyse data on the trip back while running through what-if scenarios on the initial leg of their journey. Marines train constantly, either for battle or conducting damage control drills; the best live entertainers do something similar when not planning new acts.

Second, some switch to shipboard duties that are less important when in port. As noted above astrogation, sensop, gunnery and steward duties are among those commonly filled this way. This happens often enough that, for example, when a *Suleiman* or *Empress Marava* lists only a pilot and an engineer as its crew it is generally understood that one of them is the astrogator, often the pilot. Although some try to classify astrogators as supercargo, they are vital to the operation of a jump-capable ship. Some freely volunteer to do cooking, cleaning and other housekeeping duties when in transit from port-to-port.

BUSYWORK

If faced with supercargo who fail to find ways to alleviate their boredom, a captain would be well advised to provide busywork. This could be anything from regular drills and cross training, to creating itemised lists of the contents of the ship's locker. Cleaning is common, although this should be to an objectively measurable standard of cleanliness rather than 'do it again until I say it is done', as this breeds resentment.

Those who do not offer enough stimulation should beware – the only thing more dangerous than a bored marine is a bored marine with friends.

Finally, many engage in leisure to pass the time, or use low berths or fast drug. These people are the source of the impression that supercargo crew are mostly layabout wastrels, who must be hauled from port-to-port in order to pay the bills. Giving the ship its reason to travel is of vital importance: without them, there would be no voyage in the first place. Common wisdom is to treat those who insist on this option as passengers to the maximum extent practical. This sometimes leads to conflict with wealthy but lazy ship owners who do not understand why they should engage in more useful pursuits, refusing to understand how little vacuum or jumpspace care about Credits.

THOSE IN CHARGE OF CARGO

Roles that revolve around being in charge of cargo go by many names, with differences in what they do with the cargo, particularly when not at port. On large ships, some can be part of the command crew. On small ships, having someone other than just the captain who is 'part of the command crew' tends to mean having a second in command.

- **BROKERS** buy and sell cargo and arrange freight operations. On small trading ships they are sometimes part of the command crew, perhaps even the captain or ship's owner. In addition, they research the local economy to stay aware of supply and demand, providing suggestions for a chain of destinations long before a ship has broken out of jump. A good broker, being familiar with local worlds beyond their names and profiles, can act as a guide for expeditions. Some brokers double as quartermasters.
- **PURSERS** are in charge of a ship's finances, a middle ground between brokers and quartermasters. Like quartermasters, they are part of the command crew. Usually, 'purser' is shorthand for 'broker-quartermaster' as they handle payments, whether for cargo and freight or purchasing supplies and distributing crew salaries and bonuses. Ships adherent to Aslan traditions forbid males from taking this role. Standard police procedure when investigating smuggling, contraband, or other illicit uses of a ship is to interrogate the purser first. Unmonitored pursers have the ability to skim large quantities of Credits from a ship's budget, so this position requires a lot of trust or verification. Some con artists make careers out of getting ships to hire them as pursers for several jumps, parting ways before anyone realises where their Credits have been going.
- **QUARTERMASTERS** and **LOGISTICS OFFICERS** are part of the command crew, making sure the ship has supplies to carry out its mission and informing the rest of command when a lack of supplies will make proposed missions impossible. Anyone who wants equipment must obtain the quartermaster's permission and log the withdrawal, particularly food, ammunition, parts and tools. The presence of a quartermaster can interfere with a steward's duties. Ships with quartermasters usually do not have stewards or carry paying passengers, while passenger liners generally do not hire quartermasters.
- **STEVEDORES** and **LOADMASTERS** handle the loading and unloading of cargo. This is perhaps the most dramatic example of supercargo; beyond checking and re-securing cargo while underway, there is not much these positions can accomplish while not at port. Although the role can be essential on larger freighters, many do not see it as a separate, paid position.

Typical salaries for pursers and quartermasters are comparable to an officer's, while loadmasters get general crew rates. Brokers' pay depends on whether they are part of the command crew or not, comparable to an officer's in the former case or an engineer's in the latter. If someone holding any of these jobs is the captain, they are instead paid for being the captain. Ships without personnel dedicated to these roles may have people performing them on an informal or volunteer basis, sometimes without realising it.

MAINTENANCE AND REPAIR

Many think of ship maintenance and repair as something an engineer or shipyard does while inconveniencing the crew, once a year or so. However, it is vital for all crew to have a basic understanding of simple maintenance and repair, especially on small or shorthanded ships. In an emergency, an untrained member of the crew may need to perform maintenance or repair in order to move the ship to a shipyard for major repairs and upgrades.

ANNUAL VERSUS ONGOING MAINTENANCE

'Annual maintenance' refers to putting into port for two weeks once per year, paying for a year's worth of maintenance and having it all done at that time. If done properly, the ship should not need major maintenance for another year. Any Class A or B starport worth the classification can perform this service, using imported parts if they do not have a high enough TL to manufacture them locally. Ships with custom high-TL components still require maintenance at high-TL starports.

By contrast, most of this book's readers will have an engineer who does maintenance continuously throughout the year with a monthly parts budget, termed 'ongoing maintenance'. This works just as well as annual maintenance, with minimal downtime and more ease in identifying problems before they become a serious concern. This is less practical for most non-commercial and/or large ships made in lower quantities, as their parts are frequently in shorter supply.

The main advantages of annual maintenance are that the ship is not running while maintenance is performed, making it easier and safer to perform tests, and reducing the crew's task load. Annual maintenance is recommended for ships without a workshop, although many small ship captains ignore this.

Where to perform ongoing maintenance can be a challenge. Performing maintenance or repairs on a still-running reactor or drive has similarities to performing open-heart surgery without any form of anaesthesia. A ship resting in port can offline its systems with little consequence, providing another point in favour of annual maintenance, although it is possible for ships to work around this by disassembling and overhauling systems not in use. In particular, the crew can work on the manoeuvre drive in jumpspace and the jump drive in realspace, although any engineer considering this would do well to finish their work before the ship needs to move; a trader sitting at the 100D limit without a functioning manoeuvre drive makes a tempting target. Most power plants have multiple reactors, primarily to allow for partial function should damage or accident disable one, but this allows an engineer to shut one down for maintenance while the others remain active.

When turning these systems offline, most ships will keep to lockout-tagout procedures, the practice of making certain that all systems that can injure personnel are disabled while under maintenance. This is usually accomplished with physical locks on all relevant controls to prevent activation. Software locks can be used too but are seen as easier to accidentally unlock. This may be the primary difference between annual and ongoing maintenance. At the logical extremes, annual maintenance locks out the entire ship while ongoing maintenance does not. The truth is always in between; during annual maintenance some systems can still operate, while competent engineers performing ongoing maintenance still lock out systems occasionally but make an art of optimising and scheduling them to minimise disruption to ship operations. Some disruption is inevitable and safety procedures may seem like unnecessary formalities, but they should usually be complied with as most are written in the blood of dead crew.

Another reason some ships favour annual maintenance is that maintenance requires tools which not all ships carry. This is an ill-advised cost-cutting measure as it leaves the ship unable to conduct emergency repairs but this has not prevented some captains from going without anyway. A properly stocked engineering section should have a standard starship engineer tool set for each engineer on board. The exact contents vary but a typical set includes multispectral vision goggles, an iris valve opener, a display and probes to test electronic and gravitic equipment, soldering gear, programmable

micromanipulators, pliers, wrenches, sockets and a mallet or, at higher TLs, a small gravity hammer. A good engineer tool set should provide small hull patches and a portable airlock.

RESUPPLYING A SHIP

Making sure enough of the right tools, filters, fasteners and other spare parts are stocked is all about thinking ahead. While certain components fail at mostly predictable rates, others fail on a more haphazard timeline, with the prudent strategy being to keep a spare around until needed. This is more of an issue for small ships, with less room for redundant systems and thus more unpredictable failures.

Having a workshop aboard ship means stocking a smaller diversity of spare parts, as the workshop provides the ability to manufacture parts a ship needs from common raw materials.

FOOD RESUPPLY

Food storage and resupply is a vital but often overlooked part of maintenance. Many crew know little more than that keeping food cold helps prevent it from spoiling, a practice dating back to TL0 on many worlds. Advances in food preservation allow a lettuce leaf harvested at a farm to be almost as fresh months later. Food producers apply these at the site of production, so a ship only has to provide dry storage, refrigerated storage and water.

Any ship jumping from world to world will spend somewhere from six to eight days in transit, possibly adding one or two if either or both ends involve a long trip between the jump limit and the world. This assumes that food will reliably be available at the destination; if not, multiply this by however many jumps it will take to reach food resupply, adding any days spent on worlds between jumps. Ships venturing into the unknown frequently stock four weeks of food for a return trip.

On top of having enough food, menu fatigue is worth avoiding. While some sophonts do not mind eating the same thing every day, most require a variety of food for good mental health. Purchasing bulk units of one type of food to feed the crew cheaply for an entire jump is, in most cases, a regrettable mistake. Diverse pre-made meal packs, with different tastes for 12 or 24 meals, may cost a little more but they are worth it.

Well-run ships will have the purser and steward work in tandem to stock a variety of healthy snacks, tailored to the nutritional and preferred needs of those aboard, along with ingredients for a weekly list of meals. Many passengers carry their own supplements or food if their needs vary greatly from the norm.

Food-producing biospheres do not need resupply, eliminating that need being the purpose of their existence. They provide raw ingredients, although many are tied into automated galleys that make it look like finished meals come directly from the biosphere. Ships with biospheres still utilise food storage, both for ingredients they cannot produce and a backup supply of highly condensed rations in case of food production failure. Some crews make a ritual of consuming and replacing the rations during annual maintenance; a common joke is that they do it to remind themselves why they do not let the biospheres fail. It can be a challenge to produce nutritious food with every meal. Fortunately, there are widely distributed recipes that work for most sophonts.

Some private crews make multi-sector voyages to seek out new cuisines, as even after thousands of years of interstellar civilisation, culinary innovation is always happening somewhere. Worlds off the main x-boat network are likely either to have recipes that are new to the rest of the Third Imperium or be markets for recipes at starports with x-boat service.

PREVENTATIVE MAINTENANCE

Ship crews using annual maintenance are less likely to pay attention to preventative maintenance, mistakenly thinking that only shipyards perform maintenance. Not taking a little time to fix minor issues as they occur can lead to major issues that take more time. This is why an inspection, if not a full maintenance cycle, is highly recommended when purchasing a used ship; if the former crew did not perform preventative maintenance, the ship may have expensive maintenance issues soon.

While other documents record a complete list of preventative maintenance for each individual ship, the following can give a general idea of what to look for.

Filters for air, water, waste and more need replacement on a set schedule. Some have internal monitors to let crews know when they go bad but all filters have a maximum recommended use time. Many companies build filters with chemochromic materials that change colour in the presence of contaminants, providing a colour-scale to show how saturated they are. It is vital to keep track of replacement timelines and when

current supplies will run out. Crew have fallen ill and occasionally died because of a dirty filter, which is preventable with proper planning and scheduling.

Checking gauges may seem tedious, yet it is vital to make sure they are in working order and report what they are monitoring to keep the ship running. Many times a freighter started a jump thinking they had full tanks of fuel, only to find the sensor was faulty. While the common practice of tapping the gauge only works on older spring loaded pointer style indicators, many believe this still works on electronic versions. This is generally incorrect, as electronic gauges require full computer diagnostics to tell if they are working properly.

Loose fasteners are common aboard a ship, easily checked and tightened. Manufacturers use fasteners of one kind or another for chairs, tables, hull and almost all parts of the ship. While not all bolts and nuts tighten or look the same, most fasteners are required to be a minimum of hand tight with some requiring a certain amount of torque. A fastener that refuses to stay tightened due to worn threads or a persistent vibration could be hinting at larger issues. The application of a threadlocker compound rarely solves these problems.

General cleaning may seem redundant if only a few crew are aboard but dust gathers in areas of low activity and clogs both filters and machinery. A build-up of oily residue in a drive area may seem harmless but could cause crew to slip and fall during a critical time while they are trying to fix or shut down something else. It clogs air filters and overworks ventilation and life support systems, eventually causing a breakdown of key machinery. A puddle may seem harmless to the untrained observer but may signify an irradiated coolant leak. Making sure to remove any dust and debris from walkways and important areas can help prevent any future issues and increase efficiency of the crew during their duties.

Please check the guidelines for the ship's preventative maintenance list and schedule. Failure to follow the list can result in skipping a vital component that is in desperate need of emergency maintenance.

CREW MAINTENANCE DRILLS

Drills are a form of preventative maintenance performed on a starship's crew, covering general practice such as pilot simulator runs and gunner target practice, as well as emergencies including fire, hull breaches and injuries. Announced drills are either routinely scheduled or started when convenient, such as during jump when little else is going on. They can be administered individually or involve the entire crew.

This gives the crew an opportunity to see how things should work. If unexpected complications do not arise, the run should meet all requirements and objectives. Failure in such a drill is a cause for concern, indicating that the failing crew needs immediate remedial training and should retake the drill before assignment to other duties. If the pilot crashes in a simulation of a routine approach, that is not a good sign for the ship's next port of call.

Software typically generates drills, sometimes aided by a trained instructor. The ship's captain or chief engineer sets the limits on possible scenarios; within those limits, the software can configure any potential issues. If it says the crew is fighting K'Kree pirates while undergoing a partial drive failure and internal comms malfunction, that is what they must attempt. Failure here is not necessarily a bad thing, as the goal is familiarity with unlikely scenarios. In some ways, failure can be desirable as a crew that always passes these drills with little effort most likely has the scenario restrictions set too narrowly, which may leave them inadequately prepared if something truly unanticipated occurs.

Fire, breach and suit drills typically have physical props. Roping passengers in to act as judges or hazards is typically good fun during jump, if the passengers understand what is happening and agree to participate. However, recruiting passengers against their will or surprising them during a drill can cause them to act in self-defence, perhaps with lethal force. Passengers who are not informed or do not agree to participate should be kept away from these drills. In most cases, an announcement such as, 'We are doing something in the cargo hold for a while, so please stay out until we are done' will suffice.

For small ships, unannounced drills happening at random times are widely considered a sign of a poorly run ship. Running too many unannounced drills may cause the crew to think that any emergency is just another drill and does not require a serious response. Make it clear at the start that it is a drill and only conduct them when no other important business is going on.

EMERGENCY MAINTENANCE

While this book is a handy resource, reading while attempting to fix a problem may cause more issues. If called on to handle emergencies, crew must familiarise themselves with the ship's systems and procedures in advance, so they do not respond too slowly and place themselves in jeopardy.

‘Emergency maintenance’ is an action that would normally be assigned to available maintenance crew but, due to unforeseen circumstances, is instead being conducted quickly by the nearest available crewmember. In an emergency, crew may need to turn valves, cut off breakers, unplug electronics and other such tasks. It is a peculiar type of emergency repair when there is time to wait for properly trained personnel, equipment and replacement parts to be available.

Staying calm is essential during an emergency, both to keep your own efforts focused and to serve as an example for any who might look up to you. First, evacuate any areas under immediate threat if necessary and feasible. Leading passengers and fellow crewmates away from the emergency may not take much skill but does require familiarity with the ship’s layout. If unable to make it to a safe location, quick thinking to remedy the situation may save lives, not to mention the ship. Next is to identify the type of emergency. Emergencies stemming from faulty wiring, leaks, hull breaches and malfunctioning equipment can cause much larger problems if not maintained. If you are experiencing an emergency, calmly evaluate your relative position to keep yourself safe, the extent of the emergency, the likelihood of it becoming worse, and what needs to be done to keep the problem from spreading.

REPAIRS AND DOCUMENTATION

Hastily attempting repairs during an emergency may cause more problems than waiting and doing it with a level head. If it seems necessary to perform emergency maintenance on a vital system, find an engineer immediately. Ideally, notify the chief engineer as their primary duty is to track all vital ship systems and assign other engineers to repairs. This is not an inconvenience or imposition; it is their job, especially since non-engineers should not have to perform emergency maintenance.

Non-engineering crew repairing these systems without telling anyone interferes with the engineer’s duty and puts the ship in danger. However, some repairs are time sensitive. If no engineers are available, inform them of the work done at the earliest opportunity so they can document it. Proper documentation of repairs is not ‘just some old Vilani superstition’, nor is it the cultural influence of Bwaps. It saves lives.

Leaks are probably the most reported issue aboard a ship. Solids, liquids, gas or plasma could be leaking from a pipe or storage vessel and providing a good description of the leak helps identify the problem.

The most dangerous leak on most ships is from the liquid hydrogen fuel tanks or fuel lines. Liquid hydrogen is cold enough to cause many materials to become brittle and shatter under the slightest pressure, and hydrogen mixing with an oxygen atmosphere is highly explosive under a wide range of pressures. Dealing with a liquid hydrogen leak is of paramount importance.

Once a leak is located, the most common emergency maintenance procedure is to trace the pipe and find the closest cut-off valve. Most can be closed remotely from

the bridge but some may require manual overrides. First try to establish the direction of flow of the pipe as cutting off the valve after the break may increase the pressure, causing the pipe to burst. Follow the pipe against the flow to the closest manual valve and, once closed, the leak should lessen then stop. Next, find out if the pipe is vital to the operation of the ship. If it is simple and quick to repair the pipe by replacing it or applying a patch, perform the repair then open the valve. Otherwise, most vital systems can survive a brief interruption in supply but there are limits. For example, shutting a coolant pipe will stop that pipe from leaking but may cause the ship's engine to overheat and explode if left for too long.

A hull breach can be thought of as a leak, albeit larger and more urgent than most. In the event of a hull breach, sealing off the affected compartment may be the only way to stabilise the ship. If near the breached area, heading toward the middle of the ship is often the best option. Be sure to check the cameras of affected areas for any crew or passengers in the compartment before closing airlocks or hatches to prevent further decompression. If trying to fix a hull breach manually, make sure to have all the necessary tools and patches before heading out to repair it.

Sparking wires and blown fuses are never good but electrical problems can manifest as dimmer than normal lighting, an indicator that blinks faster than normal, computer terminals that flash instead of staying on, or a mild electric shock when one touches a surface. While some may seem more urgent than others, handle all electrical problems quickly to ensure the ship is still operating normally. A faulty wire is an electrocution risk but can give a wrong readout on other vital systems, causing false alerts or hiding critical problems. An exposed and uninsulated wire could connect with something conductive, like metal or water. Electrically-charged metal decking can be especially dangerous, as it can prevent attempts to approach and fix the source of the problem. Shield high voltage areas as they can cause instantaneous death.

When repairing wire, be sure to turn off any electrical input before starting repair and ascertain if the wire is broken or corroded. If not broken but possessing damaged shielding, coat the affected area with a non-conductive material. Broken or corroded wires need replacement. When dealing with a bundle of cables, they typically have various colour insulating plastics around each wire, used to identify what needs to attach to what. A full replacement cable may be more viable when available, either as a spare part or manufactured in the ship's workshop. If neither the schematic nor a full replacement is available and there is neither a colour nor shape guide, this is probably not a repair that untrained crew should attempt, even in an emergency.

CUTTING CORNERS

One recorded incident became widely distributed for both engineering and comedic purposes. It shows a passenger finding a leak, calling it in via the nearest intercom but instead receiving a generic request for them to handle it. This led to the passenger looking around for anything to fix the pipe, finding some duct tape, fixing the piping with the duct tape, then promptly informing a ship's engineer who was passing by. Unfortunately, the head engineer, in an attempt to save money, had previously switched the ship's original piping with discount pipes that reacted with the ship's discount duct tape and was starting to melt and burn by the time the engineer showed up, causing a panic to put out the fire.

The ship's internal documentation had never been updated to reflect the replacement of the pipes, so there was no way the passenger could have known before conducting emergency maintenance. The incident never went to court but there was universal agreement among legal scholars that the passenger would never have been found at fault, especially since they promptly informed the ship's engineer afterward.

Less than 10 years later, the ship would be lost when its manoeuvre drive abruptly failed while taking off. Based on analysis of the wreckage, the reason was a failed attempt by the ship's engineer to reuse the drive as a gravitic forge. There were no notes about these modifications in the ship's computer, although they were at least a week old, which should have provided adequate time to document them.

DECKPLAN REVISIONS

The 'optimal' deck layout for any given class of ship is often a highly subjective matter. Many new ship captains have issues with the deckplans of the ship they just acquired. Minor interior alterations are a

standard service offered as part of annual maintenance by Class A or B starports, since it involves partially disassembling the ship anyway.

Costs depend on the nature of the revisions. If they are performed during the annual maintenance, and their cost scales alongside this, it is common to price this service as a modifier to the cost of that maintenance. Any changes that move major systems, such as drives or power plants, or involve changes to the outer hull, such as sensors, weapons and airlocks, will at the very least triple the maintenance cost, and usually charges will be much higher. Any changes not involving these components may only double the costs. This only covers moving around existing components; adding, removing or resizing components has a different price and schedule. If a ship has a salvaged component, it can be installed as a deckplan revision, with the exception of standard turret weapon mounts. Being relatively easy to remove and install, turret weapons are often installed for free with purchase so long as the ship has space available. Barbette mounts and larger weapons do not get this benefit.

The owner must submit all planned revisions before the work begins. There is no capability to accommodate changes once work starts, save by paying full price and starting the work period anew. Many a noble paid the extra cost without blinking but raged at the prospect of being without their ship for one more day, not comprehending why their request caused such delays.

These revisions are expensive because of the extra work involved. For example, converting two adjacent staterooms into one large luxury stateroom will require removing a wall and entirely rearranging the interior. While this may seem simple, the shipyard will have to move wiring, pillars, pipes, air ducts and extend larger items. While adding a new airlock may appear easy, a standard airlock may not fit the area so the shipyard will need to resize it, not to mention altering the outer hull, starting with moving any sensor nodes and jump drive emitters, then tuning them to work optimally in new locations. Even replacing the sink in the galley with a deeper one often requires restructuring the piping and widening the cabinet.

Those who wish to avoid these costs should purchase a ship built for their preferred missions. While a shipyard can theoretically modify any ship to a shipowner's or crew's needs, researching the options can keep the cost down. For example, it is less expensive to build a *Seeker* than to build a *Suleiman* and then convert it into a *Seeker*. Regardless, many small ship owners find themselves in possession of a ship not optimised for their intended purpose, in which case conversion may make more sense.

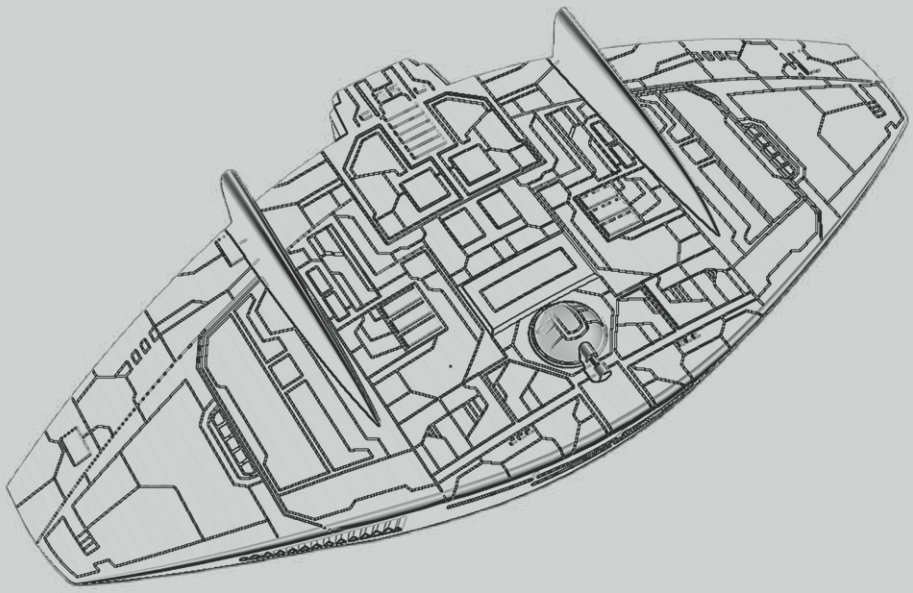
When modifying a ship, care must be taken to leave the ship spaceworthy. One noble loved his *Animal*-class so much that rather than trade it in or buy a second ship, he paid many times extra on a low-tech world (which lacked trained safety inspectors, who had objected to his plans at the first starport he tried) to have a large hatch installed between the launch hangar and the holding tank so he could put a large live animal in there. This seemed to work until the hatch seals gave way while the hangar doors were open in orbit, resulting in explosive decompression.

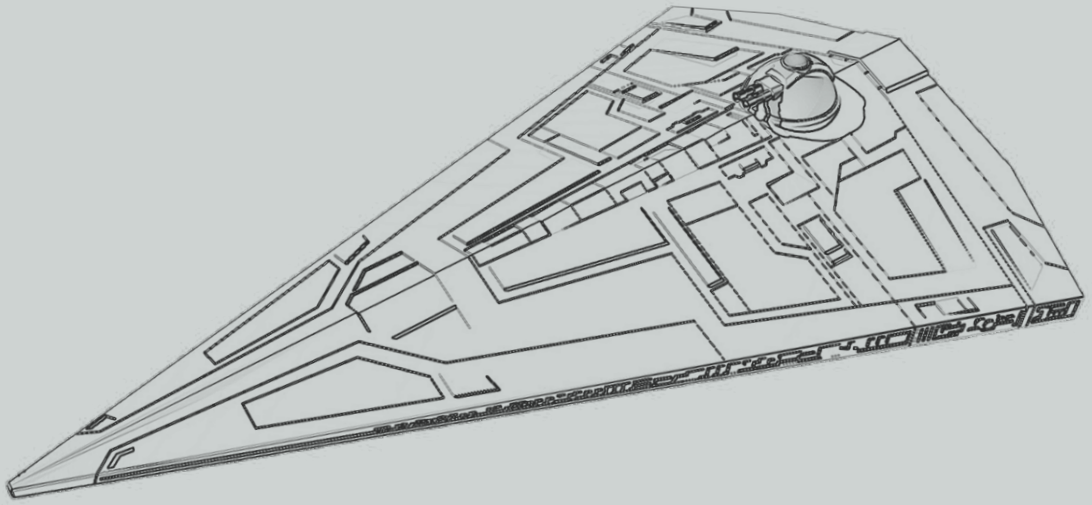
SHIP RETIREMENT

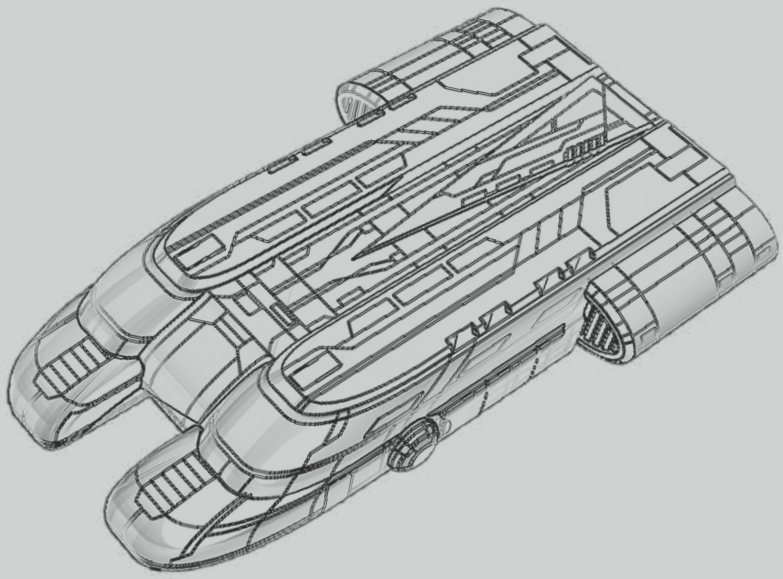
A starship with good maintenance that never suffers much damage and serving a purpose that remains viable can theoretically last for 1,000 years or more. The very few actual 1,000-year-old ships typically serve mundane roles for which demand never went away or are maintained as functioning museum ships. Most examples rarely have any original parts aside from sections of the hull, with enough replaced material to make a new ship several times over.

When wanting greater capability beyond what it is practical to modify a ship for, the ship's owners can sell it or have another vessel constructed. Ships whose owners fail to pay their mortgages wind up sold off if they are not stolen, lost, or destroyed first. This change in ownership does not directly affect the lifespan of a ship, although statistically ships that transfer owners this way see poorer maintenance overall.

Excessively damaged or worn down ships eventually wind up in the hands of shipbreakers, performing what is sometimes termed 'final annual maintenance' as the procedure is quite similar; systems are dismounted and extensively tested, although with an eye toward resale rather than reinstallation. There are occasions where, for legal, financial or sentimental reasons, the owners want to retire and replace a damaged ship with another but wish to act as if it was the same ship. In these cases, the new ship gets priority for reusable components of the old vessel and transfers the nameplates over. However, the Imperial registry is for a new ship with the same name, recognised as a separate entity.







SHIP WALKTHROUGH

Ten thousand years have passed since the Vilani discovered the jump drive and started the modern era of interstellar civilisation. Charted Space consists of many thousands of inhabited worlds. The Third Imperium alone consists of somewhere from 15 to 20 trillion sophonts, most of them human. Given these numbers, it should come as no great surprise that there is a staggering variety of starship designs.

This book presents three common ships: the safari ship, the scout/courier and the far trader. In all three cases, there are a number of internal layouts available when a ship is first manufactured and many captains customise further, so the examples selected are typical fresh-from-the-shipyard as representatives of each class: the *Animal*-class *Finicky Platypus*, the *Suleiman*-class *Dark Poni* and the *Empress Marava*-class *Gustus*.

ANIMAL (TYPE K) SAFARI SHIP

The *Animal* is a widely known 'expedition ship', designed to land on poorly developed worlds with exotic fauna. This ideal runs into local laws restricting where starships may land often enough that the ship carries two subcraft, one with an ATV, to facilitate approach to wilderness areas. It carries a turret for protection against pirates when headed into systems where this is a problem. Those who target the largest megafauna sometimes use it in their hunts, fitting laser drills, since the limited range by ship standards is rarely an issue for this purpose. When using ship weaponry this way, care must be taken to make sure there is enough of a trophy remaining.

SULEIMAN (TYPE S) SCOUT/COURIER

The *Suleiman* is believed to be among the most massively produced designs of any starship in Charted Space. It was originally designed to the specifications of the Imperial Interstellar Scout Service as a multipurpose vessel capable of exploration, couriering and other common scout duties. Like most multipurpose designs, it wound up being a jack-of-all-trades but a master of none. For example, many criticise the jump performance of only two parsecs, for both long distance courier services and heading to distant unexplored star systems. Suleiman hulls can be converted to several variants, such as the Seeker. It is estimated that over a million *Suleiman* hulls have been manufactured, including all variants, although less than 50,000 remain in service as *Suleimans* in the Third Imperium.

EMPRESS MARAVA (TYPE A2) FAR TRADER

While not as famous as the *Beowulf* class, the *Empress Marava* is a capable trading vessel. It costs a little more and carries a little less but comes armed by default, which is enough to deter many pirates before they move close enough to tell if this ship actually has weapons. It can jump two parsecs, opening routes not available to free traders. The class and many ships within it are named for Emperors of the Flag and similarly short-lived high-importance people and organisations. In ironic contrast, most *Empress Maravas* wind up serving low importance routes but are long lived.

ANIMAL SAFARI SHIP

TYPE: K

TL12		Tons	Cost (MCr)
Hull	200 Tons, Streamlined	—	12
M-Drive	Thrust 1	2	4
J-Drive	Jump 2	15	22.5
Power Plant	Fusion (TL12), Power 105	7	7
Fuel Tanks	J-2, 4 weeks of operation	41	—
Bridge		10	1
Computer	Computer/5bis	—	0.045
Sensors	Civilian Grade	1	3
Weapons	Double Turret (empty)	1	0.5
Craft	Docking Space (20 tons)	22	5.5
	Launch	—	2.63
	ATV (on launch)	—	0.155
	Docking Space (4 tons)	5	1.25
	Air/raft	—	0.25
Systems	Fuel Processing Plant (40 tons/day)	2	0.1
	Fuel Scoops	—	—
	Multi-Environment Equipment	0.8	0.4
	Multi-Environment Holding Tanks	16	—
Staterooms	Standard x11	44	5.5
Software	Manoeuvre	—	—
	Library	—	—
	Jump Control/2	—	0.2
	Intellect	—	—
Common Areas	—	13	1.3
	Trophy Lounge	7	0.7
Cargo		13.2	—

Crew

Pilot, Astrogator, Engineer, Medic, Steward

Hull: 80

Running Costs

MAINTENANCE COST

Cr5103/month

PURCHASE COST

MCr61.227

Power Requirements

Basic Ship Systems

40

Manoeuvre Drive

20

Jump Drive

40

Sensors

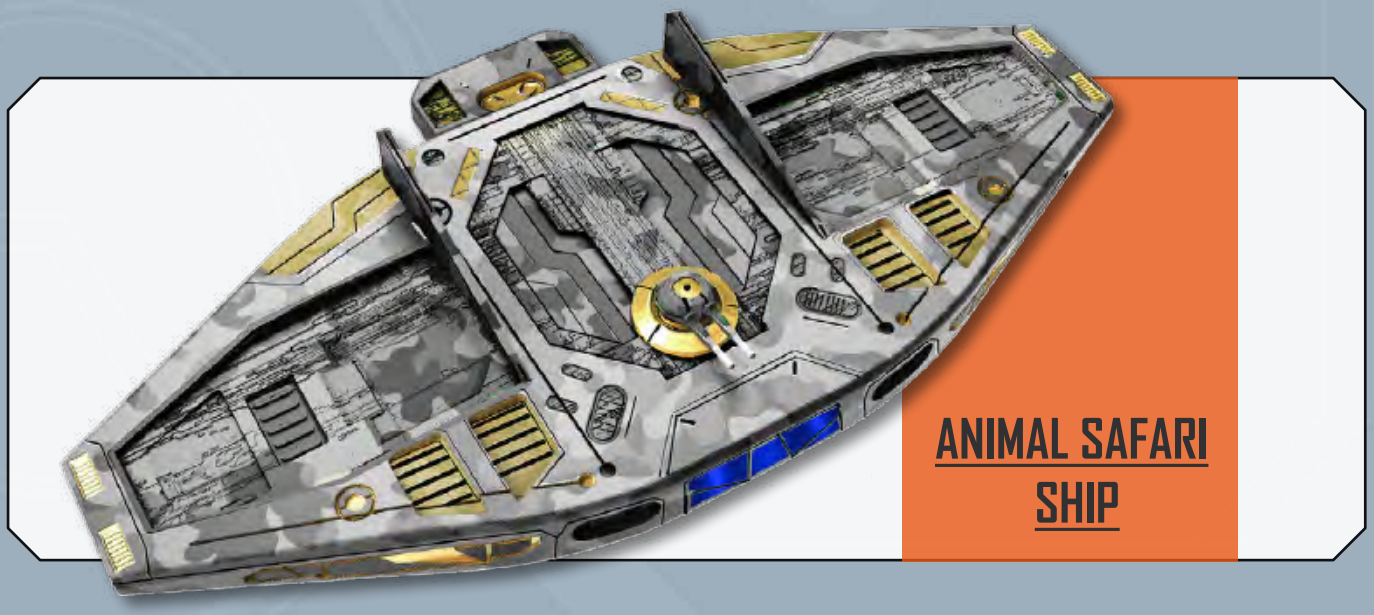
1

Fuel Processor

2

Multi-Environment Equipment

1

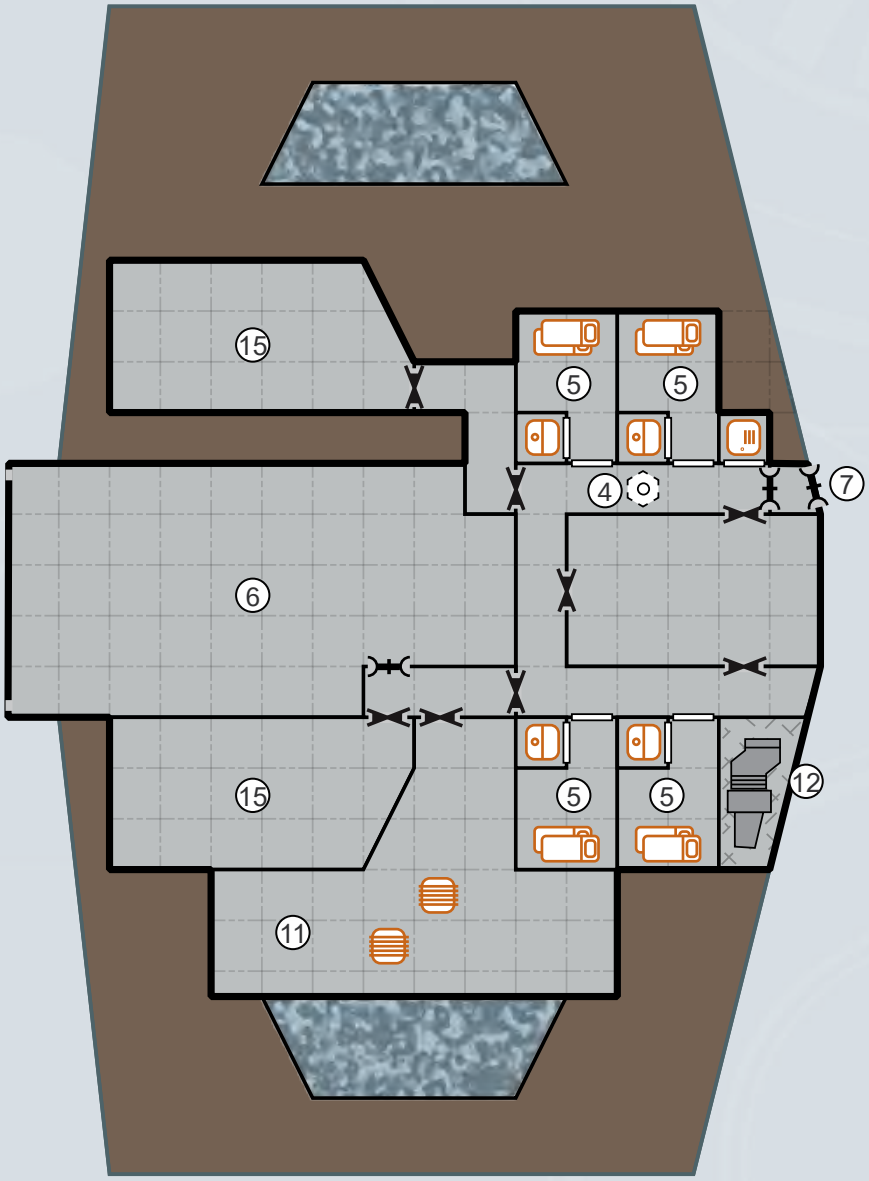


ANIMAL SAFARI SHIP

1 square = 0.5 Ton (1.5m x 1.5m x 3m)

LEGEND

1. Sensors
2. Bridge
3. Office
4. Ladder/Lift
5. Stateroom
6. Docking Space
7. Airlock
8. Power Plant
9. Jump Drive
10. Manoeuvre Drive
11. Cargo Hold
12. Fuel Processor
13. Turret
14. Commons
15. Multi-Environment Holding Tanks

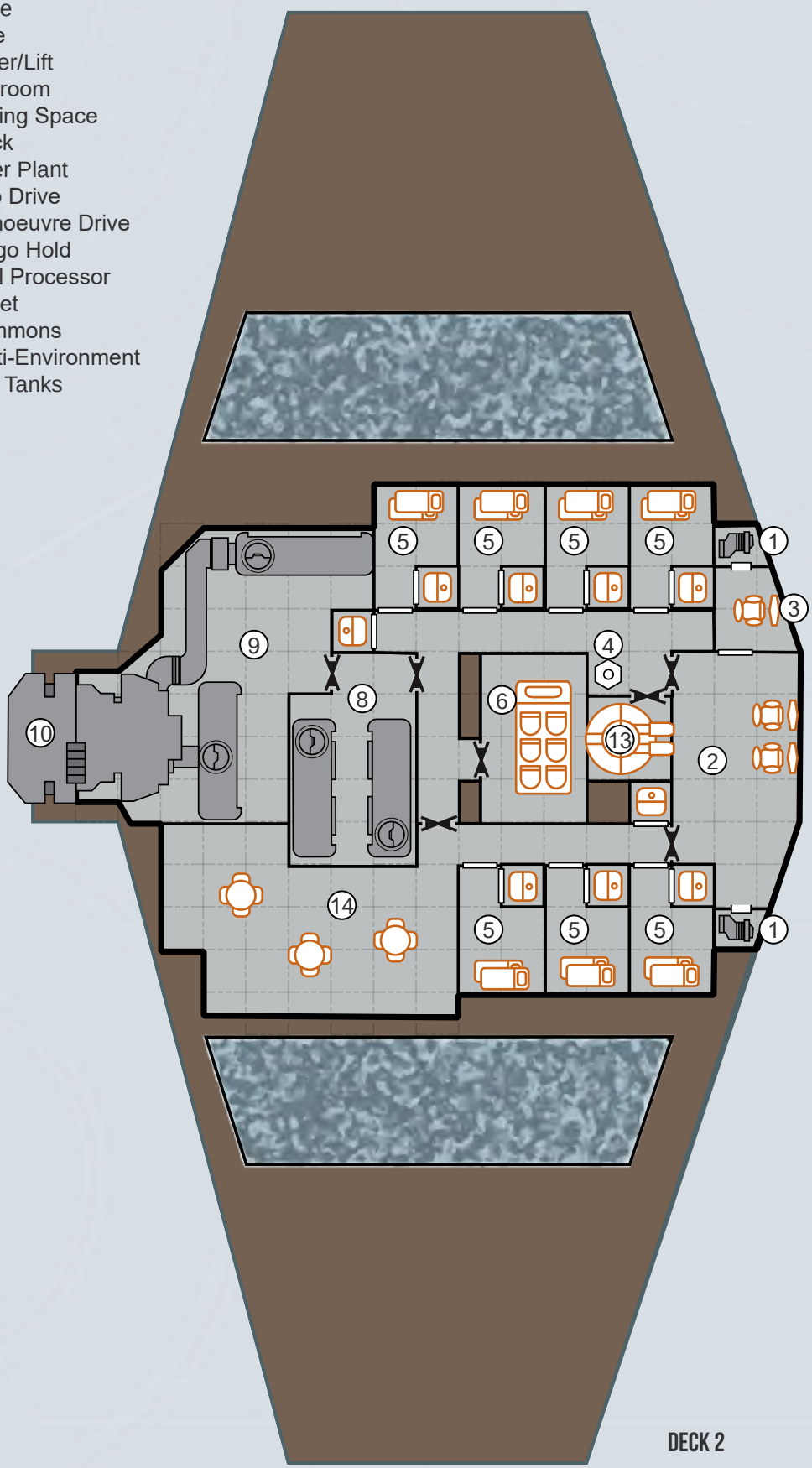


DECK 1

1 square = 0.5 Ton (1.5m x 1.5m x 3m)

LEGEND

1. Sensors
2. Bridge
3. Office
4. Ladder/Lift
5. Stateroom
6. Docking Space
7. Airlock
8. Power Plant
9. Jump Drive
10. Manoeuvre Drive
11. Cargo Hold
12. Fuel Processor
13. Turret
14. Commons
15. Multi-Environment Holding Tanks



DECK 2

SULEIMAN SCOUT/COURIER

TYPE: S

TL12		Tons	Cost (MCr)
Hull	100 Tons, Streamlined	—	6
Armour	Crystaliron, Armour: 4	6	1.2
M-Drive	Thrust 2	2	4
J-Drive	Jump 2	10	15
Power Plant	Fusion (TL12), Power 60	4	4
Fuel Tanks	J-2, 12 weeks of operation	23	—
Bridge		10	0.5
Computer	Computer/5bis	—	0.045
Sensors	Military Grade	2	4.1
Weapons	Double Turret (empty)	1	0.5
Craft	Docking Space (4 tons)	5	1.25
	Air/raft	—	0.25
Systems	Fuel Processing Plant (40 tons/day)	2	0.1
	Fuel Scoops	—	—
	Probe Drones x10	2	1
	Workshop	6	0.9
Staterooms	Standard x4	16	2
Software	Manoeuvre	—	—
	Library	—	—
	Jump Control/2	—	0.2
	Intellect	—	—
Cargo		11	—

Crew

Pilot, Astrogator, Engineer

Hull: 40

Running Costs

MAINTENANCE COST

Cr3079/month

PURCHASE COST

MCr36.9405

Power Requirements

Basic Ship Systems

20

Manoeuvre Drive

20

Jump Drive

20

Sensors

2

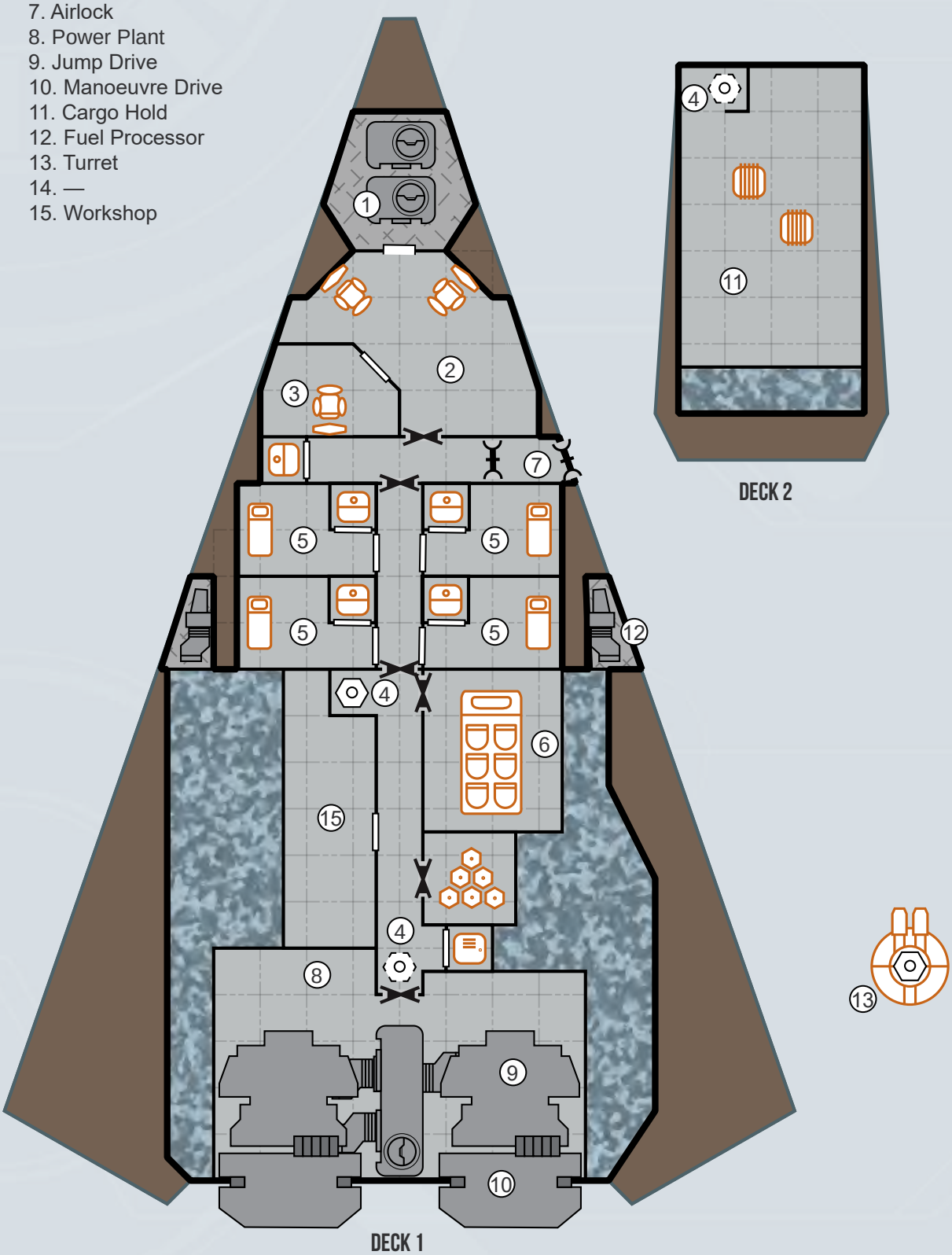
Fuel Processor

2

1 square = 0.5 Ton (1.5m x 1.5m x 3m)

LEGEND

1. Sensors
2. Bridge
3. Office
4. Ladder/Lift
5. Stateroom
6. Docking Space
7. Airlock
8. Power Plant
9. Jump Drive
10. Manoeuvre Drive
11. Cargo Hold
12. Fuel Processor
13. Turret
14. —
15. Workshop



DECK 1

DECK 2

EMPRESS MARAVA FAR TRADER

TYPE: A2

TL12		Tons	Cost (MCr)
Hull	200 Tons, Streamlined	—	12
M-Drive	Thrust 1	2	4
J-Drive	Jump 2	15	22.5
Power Plant	Fusion (TL12), Power 90	6	6
Fuel Tanks	J-2, 4 weeks of operation	41	—
Bridge		10	1
Computer	Computer/5/bis	—	0.045
Sensors	Civilian Grade	1	3
Weapons	Double Turret (beam lasers) x2	2	3
Craft	Docking Space (4 tons)	5	1.25
	Air/raft	—	0.25
Systems	Fuel Processing Plant (40 tons/day)	2	0.1
	Fuel Scoops	—	—
	Loading Belt (TL7)	1	0.003
	Cargo Airlock x2	6	0.6
Staterooms	Standard x10	40	5
	Low Berth x4	2	0.2
Software	Manoeuvre	—	—
	Library	—	—
	Jump Control/2	—	0.2
	Intellect	—	—
Common Areas		10	1
Cargo		57	—

Crew

Pilot/Astrogator, Engineer, Steward, Gunners x2

Hull: 80

Running Costs

MAINTENANCE COST

Cr4513/month

PURCHASE COST

MCr54.1582

Power Requirements

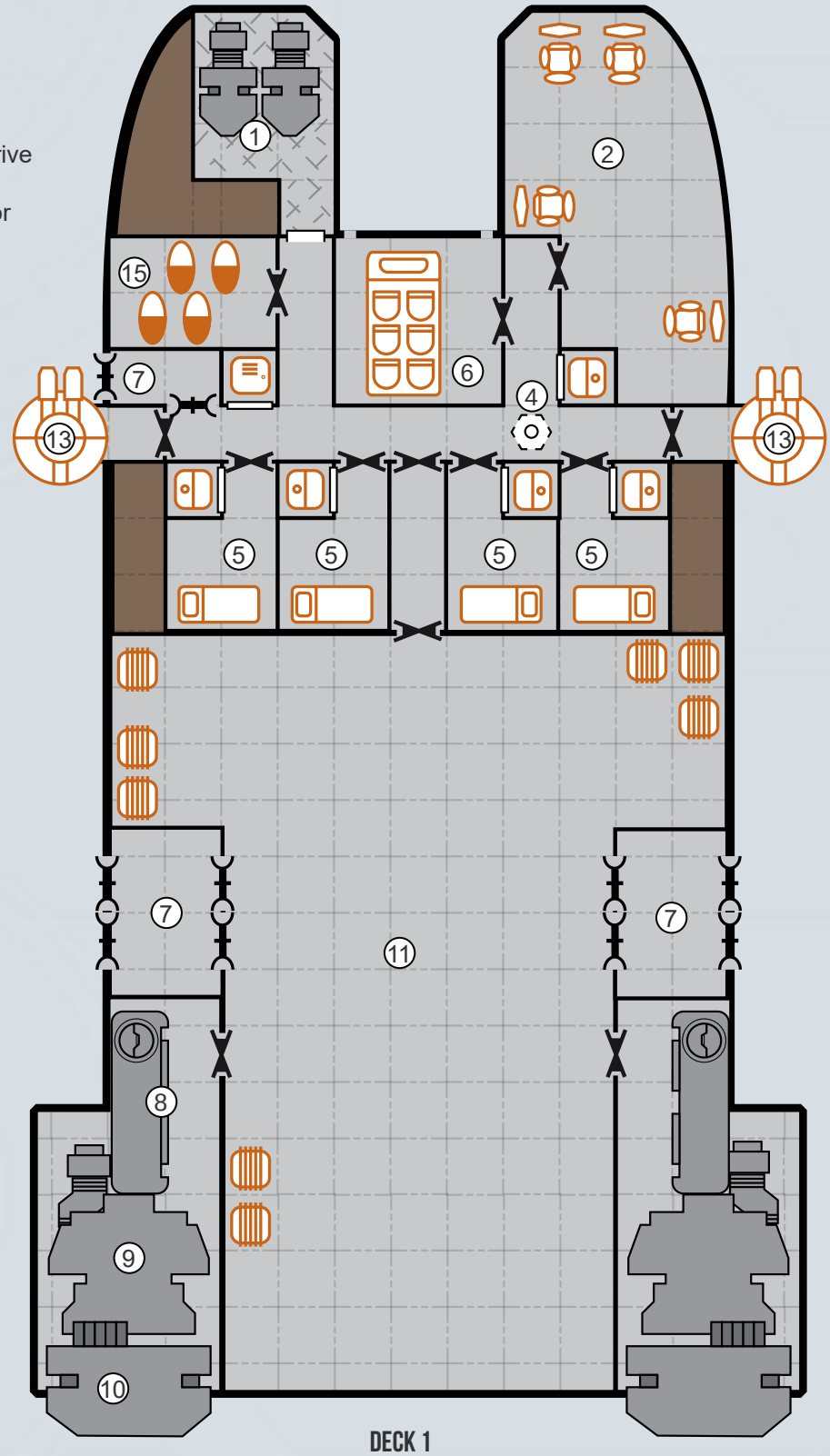
Basic Ship Systems	40
Manoeuvre Drive	20
Jump Drive	40
Sensors	1
Fuel Processor	2
Weapons	18
Loading Belt	1
Low Berths	1

EMPRESS MARAVA FAR TRADER

1 square = 0.5 Ton (1.5m x 1.5m x 3m)

LEGEND

1. Sensors
2. Bridge
3. —
4. Ladder/Lift
5. Stateroom
6. Docking Space
7. Airlock
8. Power Plant
9. Jump Drive
10. Manoeuvre Drive
11. Cargo Hold
12. Fuel Processor
13. Turret
14. Commons
15. Low Berths

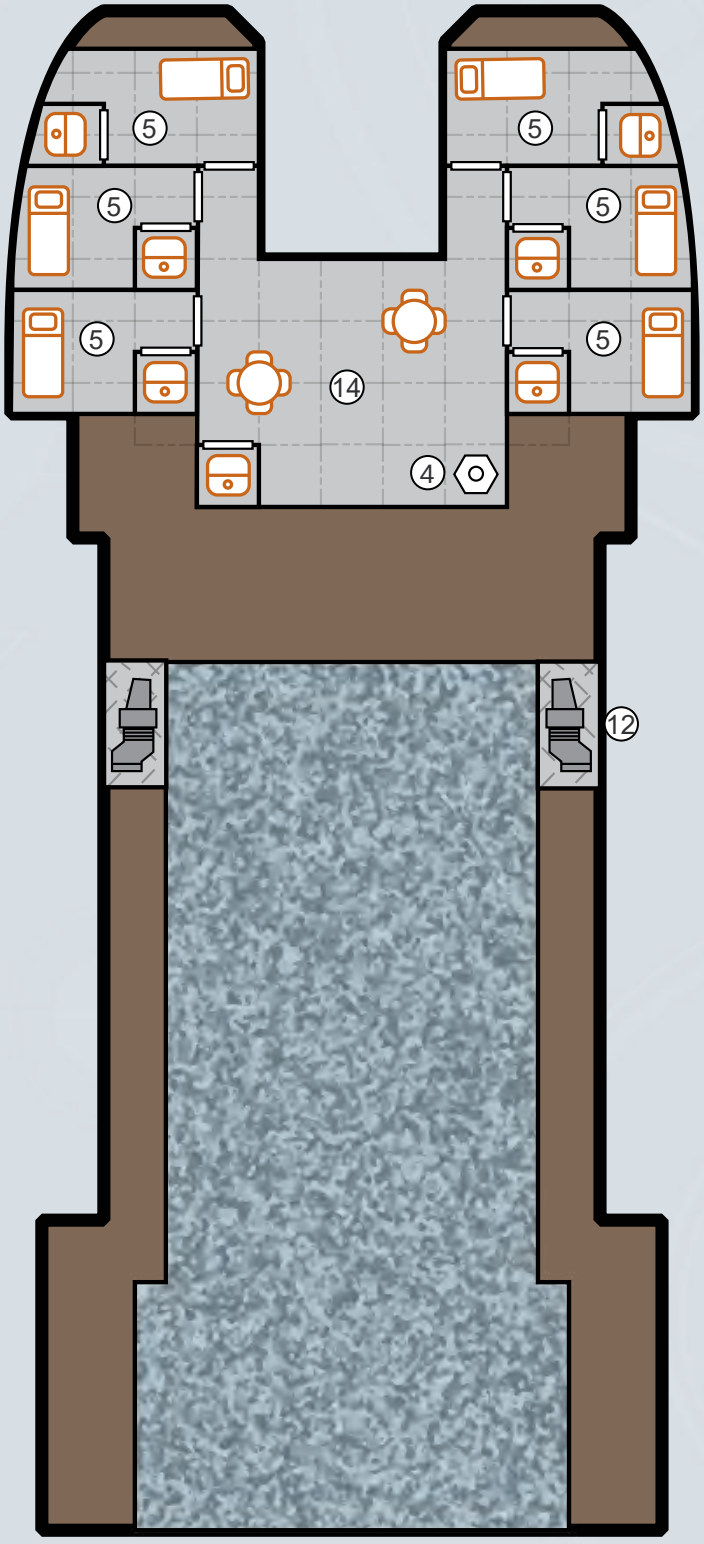


DECK 1

1 square = 0.5 Ton (1.5m x 1.5m x 3m)

LEGEND

1. Sensors
2. Bridge
3. —
4. Ladder/Lift
5. Stateroom
6. Docking Space
7. Airlock
8. Power Plant
9. Jump Drive
10. Manoeuvre Drive
11. Cargo Hold
12. Fuel Processor
13. Turret
14. Commons
15. Low Berths



DECK 2

1. SENSORS

Most ships have small sensor/communicator units distributed over the hull, forming an antenna the size of the entire ship. Being ship-wide, these tend not to be noted on deckplans.

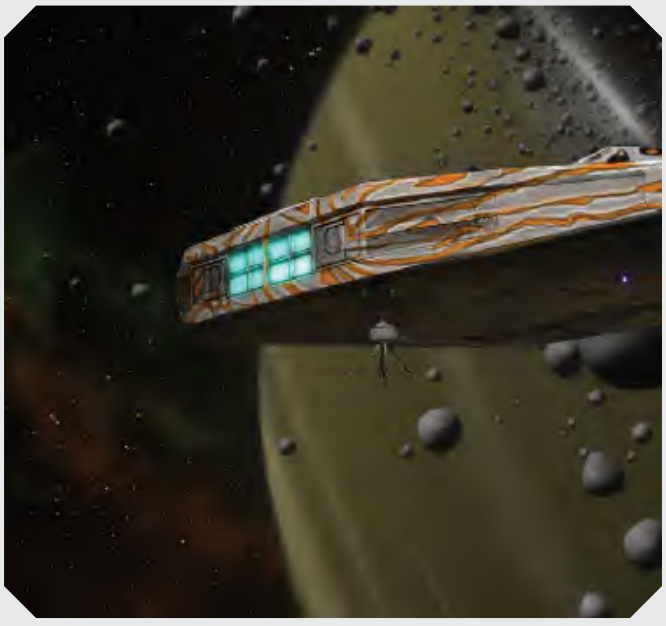
What is noted on deckplans are any large sensor units distinct from the ship's primary computer, customarily mounted on the edge of the ship, usually under an armoured cover. For many non-military ships, advanced sensors are seen as a needless expense, with the resulting space usage so tiny that even processing nodes do not show up on deckplans. This is not the case for our example ships, for differing reasons.

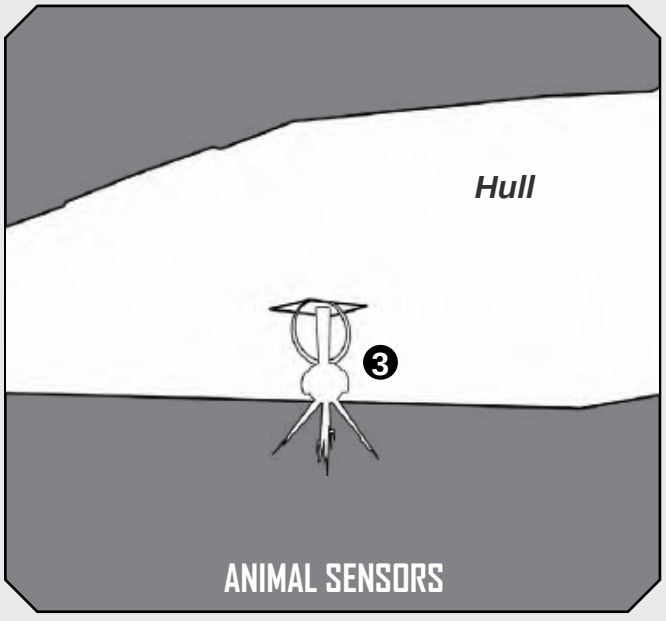
Of the three examples, the *Animal* most often uses its sensors at relatively close range, although most hunting competitions with any notion of fairness will ban use of shipboard sensors unless all entrants have access to similar-quality sensors aboard similar-size ships. However, the *Animal* is designed to support safaris in extreme wilderness conditions where such regulations rarely apply.

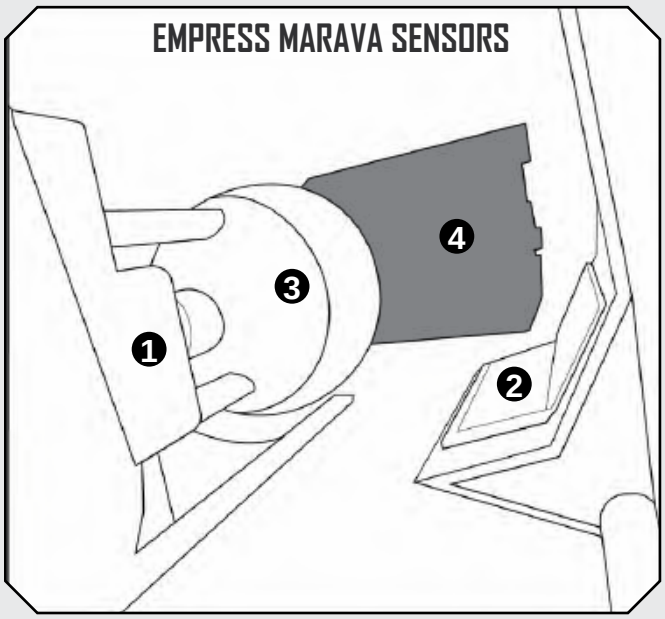
That the *Suleiman* has the most complex sensor array of the three should come as no surprise given its original mission, although the use of the electronic warfare capability is not immediately clear to those who think it primarily an explorer. Even when it travels to places thought to be uninhabited, there is always a risk of pirates or others who cannot let visitors escape alive. Then there is the 'courier' part of its 'scout/courier' mission, often carrying packages important enough that others may wish to waylay them. This may not always be through direct violence as simply jamming a courier's communications can prevent it from completing its mission. As a result, the *Suleiman* mounts a military-grade sensor suite.

The *Empress Marava*'s sensors are more general purpose, from detecting would-be pirates and finding otherwise hidden downports, to scanning planetoids for mineral deposits. Some captains strip out the processing nodes to wrest a few more tons of cargo space and slightly lower maintenance costs, although this ship typically undertakes such a variety of missions that they will frequently be useful.

1. Sensor processor
2. Data input from sensors
3. Radio transceiver antenna array
4. Radio-translucent outer cover






EMPRESS MARAVA SENSORS
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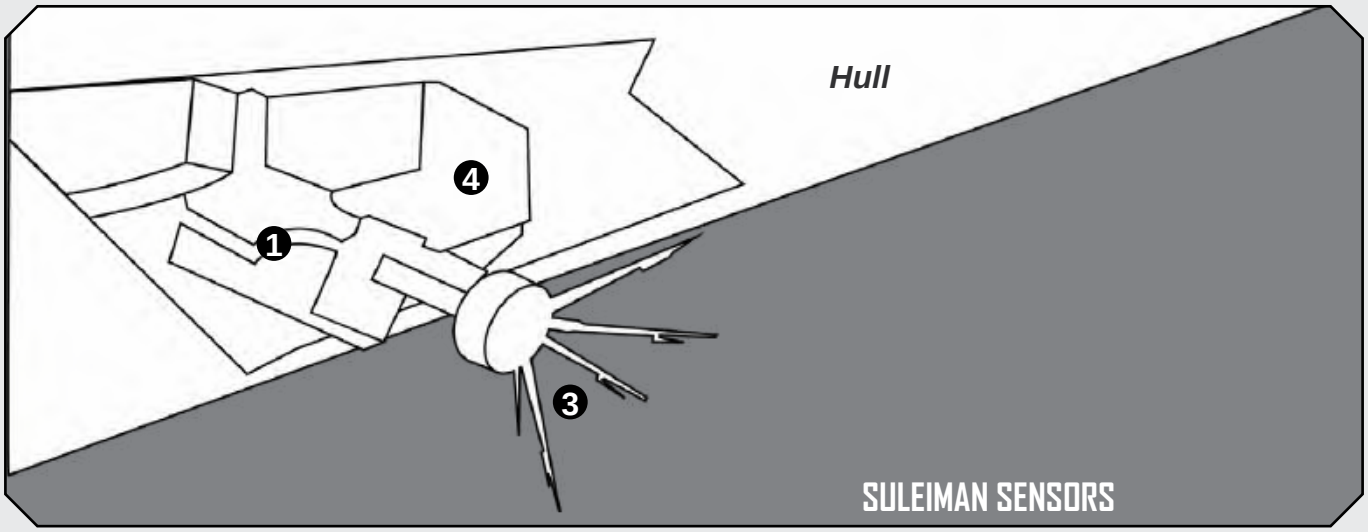
3
4


Hull
1
3
4
SULEIMAN SENSORS

2. BRIDGE

From the austere functionality of a freighter or mining ship to the near-overwhelming array of information available on a military vessel, the bridge best exemplifies what role a ship is intended to perform.

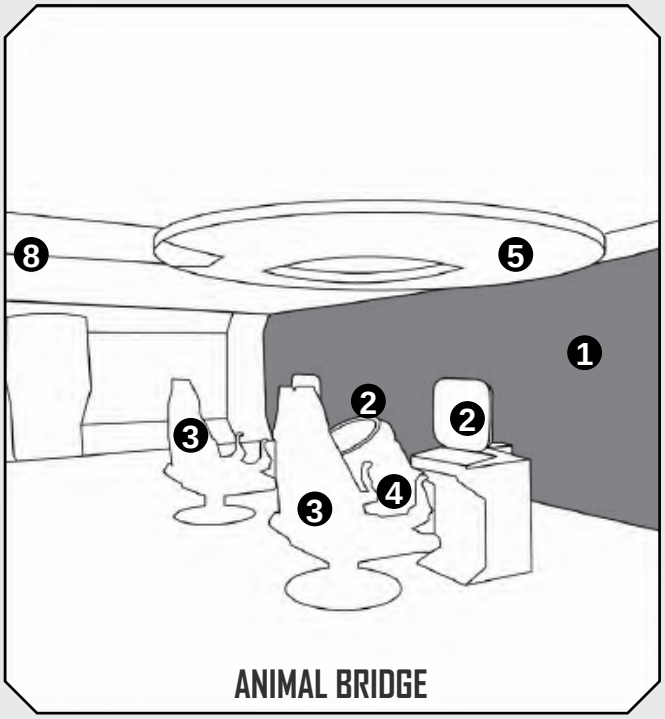
Of the three ship classes here, the *Animal*'s bridge is the most obvious example as it normally only has two control stations, encouraging the engineer, medic and steward to perform duties elsewhere. The bridge's location emphasises style and luxury over security. The forward viewport provides a commanding view over everything in front of the ship, serving as an observation post for hunting expeditions and a panoramic view for more luxurious affairs. For the former, this viewport is often overlaid with sensor information to maximise situational awareness. For the latter, the viewport extends to the trophy lounge below the bridge, allowing a better view whilst entertaining guests.

The *Suleiman*, on the other hand, is almost pure utility. Although the bridge is poorly protected near the front of the ship, it is positioned behind some not insignificant bulk to provide cover from head-on fire, while capitalising on the *Suleiman*'s sloped hull for additional protection. Unlike the *Animal*'s relative luxury, the *Suleiman*'s bridge is typically left austere. The deck is textured metal and surrounding bulkheads are given simple cushioning, in the event of grav-plate failure.

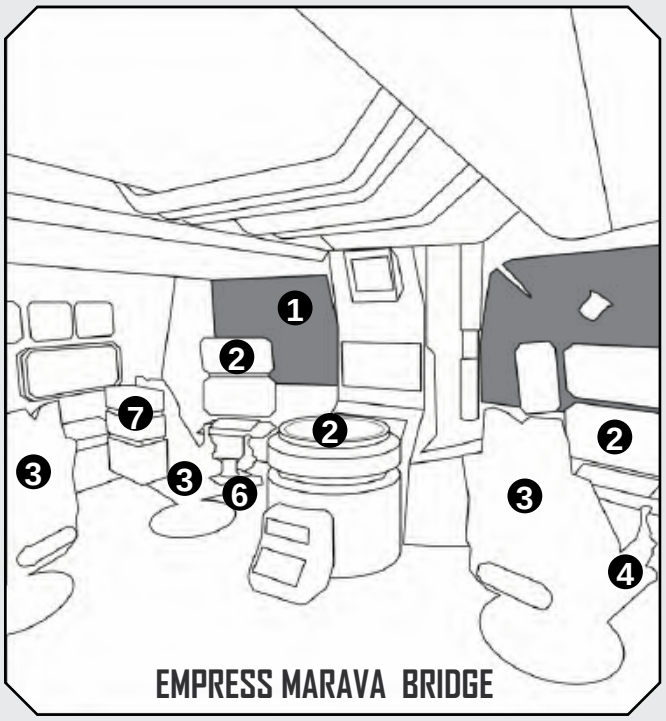
An *Empress Marava*'s bridge strikes a balance. Although it lacks the grand vista provided by an *Animal*'s bridge, it nonetheless maintains a greater degree of comfort than a *Suleiman*, encouraging its use as an informal commons. Although the *Empress Marava* does have a formal commons, these are located on the upper deck with the passenger staterooms, resulting in them being almost entirely allocated for passengers. The crew co-opting the bridge as a commons helps facilitate greater teamwork, which can assist in the wider range of roles the *Empress Marava* is expected to undertake. There is one slight curiosity surrounding the bridge, however; it is mounted off-centre.

Regardless of their differences, any bridge will have information readouts available to the crew in addition to piloting controls. While the bridge is the traditional place for a captain to give orders from, most small ships have crews too small to need a dedicated captain, officer or other administrator, which is why these bridges lack a captain's console, whether or not there is an attached office.

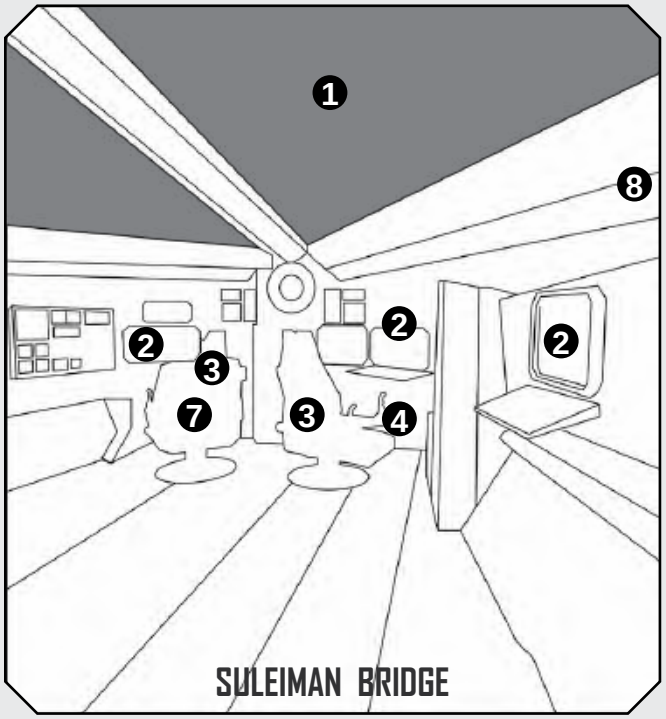
1. Forward viewport
2. Touchscreen control panel
3. Control seat/acceleration couch
4. Armrest-mounted control grip
5. Overhead holodisplay
6. Cupholder/folding tray
7. Vehicle emergency kit
8. Security camera and fire suppression projector



ANIMAL BRIDGE



EMPRESS MARAVA BRIDGE



SULEIMAN BRIDGE

3. OFFICE

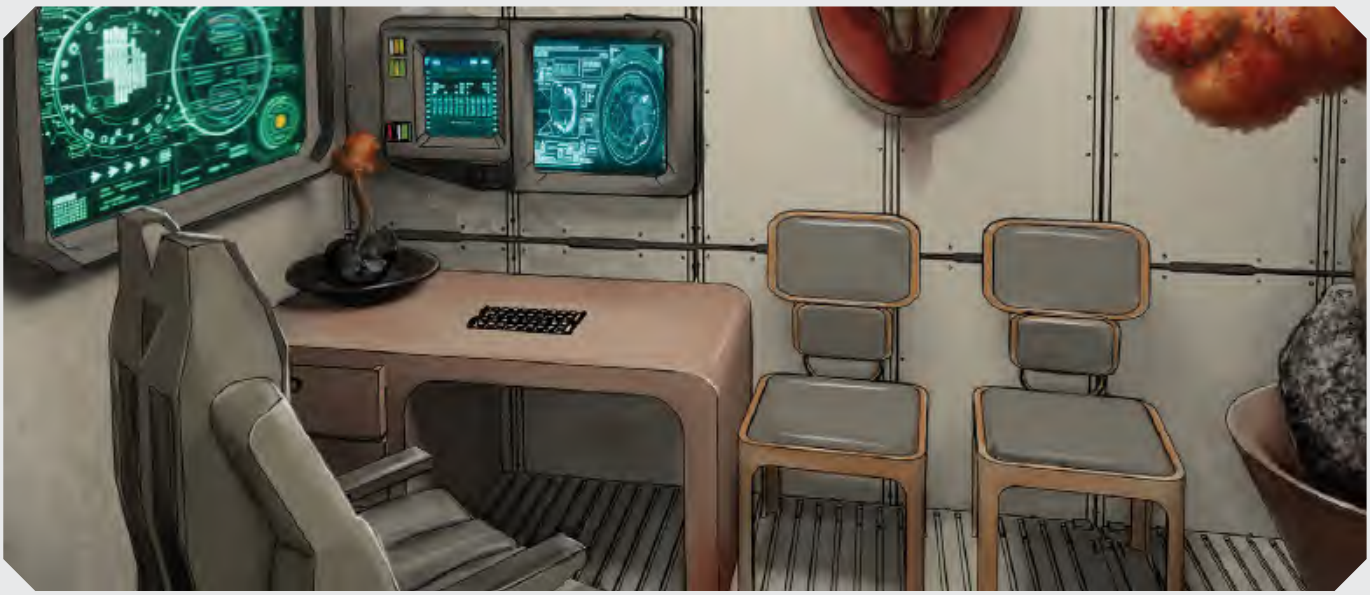
While a ship's office is used primarily as a meeting place, this is a good example of where the same space can be used for different purposes.

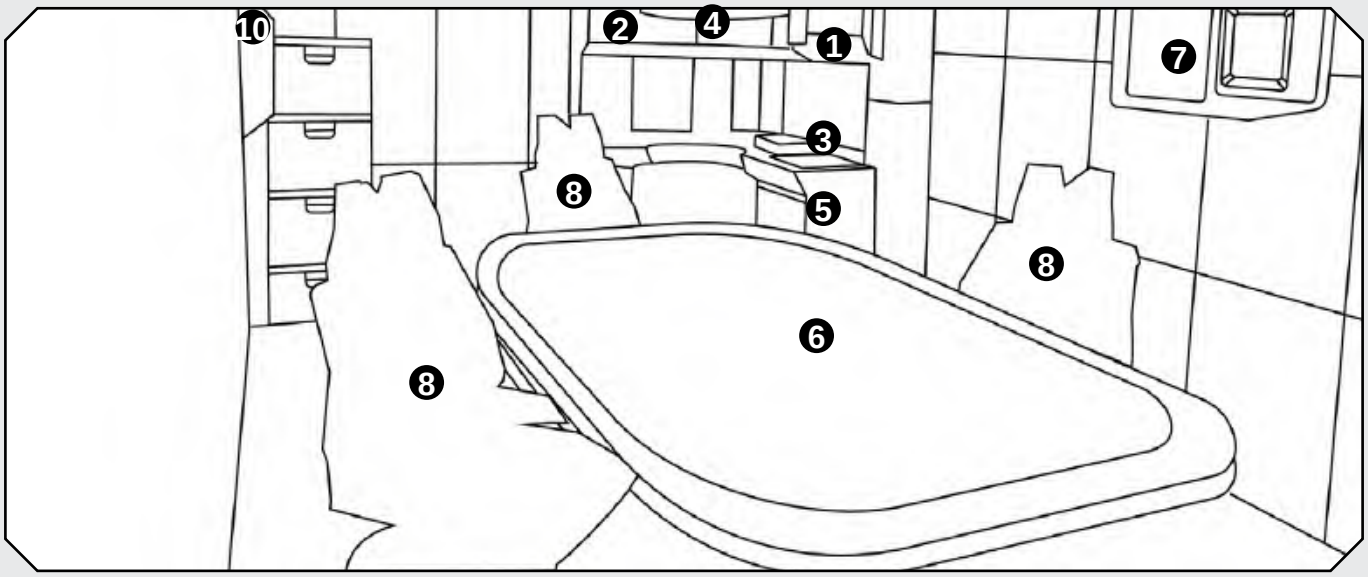
The *Animal* tends to use its office space as an area where the captain can have a quiet meeting separately from the prying ears of the crew. The desk is not standardised in design or placement and often a reflection of the captain. A tidy captain will have things neatly arranged, while others may have papers and equipment spewing from drawers and stacked up on flat surfaces. There is barely room for three chairs, to accommodate the not uncommon situation where a captain needs to 'talk' with two other people but actually intends to initiate them talking with each other.

The builders of the *Suleiman* realised the importance of an office to negotiate deals and hold bureaucratic meetings. While not luxurious, the design is tailored to these long meetings, with many ships installing comfortable chairs and a mini-kitchen, focused on preparation of food and drink during ongoing negotiations. Given its purpose, it is less customisable than the *Animal*'s office despite being larger, with most standard fixtures being difficult or inconvenient to modify. Chairs are usually padded and identical, with the captain taking the lone chair at the far side of the table. Two chairs are normally set up on the side closer to the door but more can be inflated and deployed when needed, up to a cramped maximum of four visitor seats. The table is usually fixed, set slightly back from the centre of the room to give more space for visitors. In practice, the mini-kitchen is more often used to help sustain crew morale as the *Suleiman* lacks proper commons, only seeing thorough cleaning when and if used for diplomatic functions. It is widely suspected this design was the result of bureaucratic kickbacks and lobbying.

The *Empress Marava*, like many ships, has no office.

1. Mini-kitchen (Suleiman only)
2. Microwave (Suleiman only)
3. Sink (Suleiman only)
4. Washing/drying unit (Suleiman only)
5. Food storage cabinets (Suleiman only)
6. Meeting table (Suleiman only)
7. Holographic projection unit (Suleiman only)
8. Chairs
9. Captain's desk (Animal only)
10. Security camera and fire suppression projector




10
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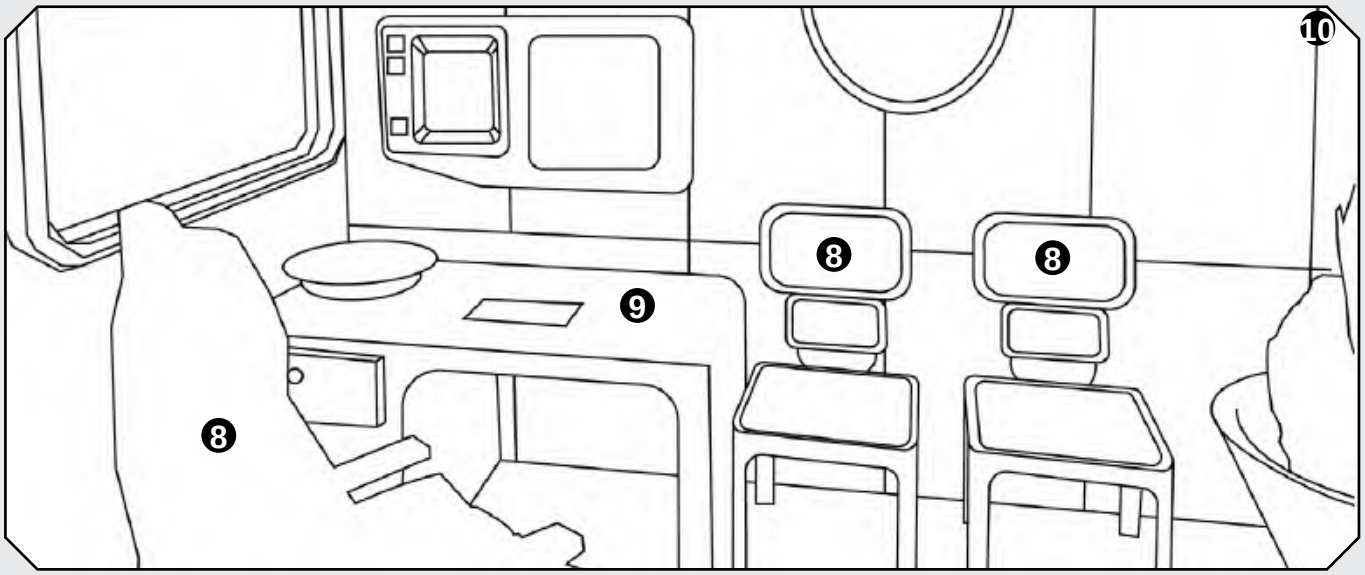

10
8
8
9
8

4. LADDER/LIFT

As all ships presented have more than one deck, they must provide some means of interdeck transit. Both ladders and lifts are used; stairs are not found on any of these ships as there is not enough foot traffic to justify their use. When new, the *Animal*, *Empress Marava* and *Suleiman* have a standard lift and ladder system installed between the iris valves of their two decks.

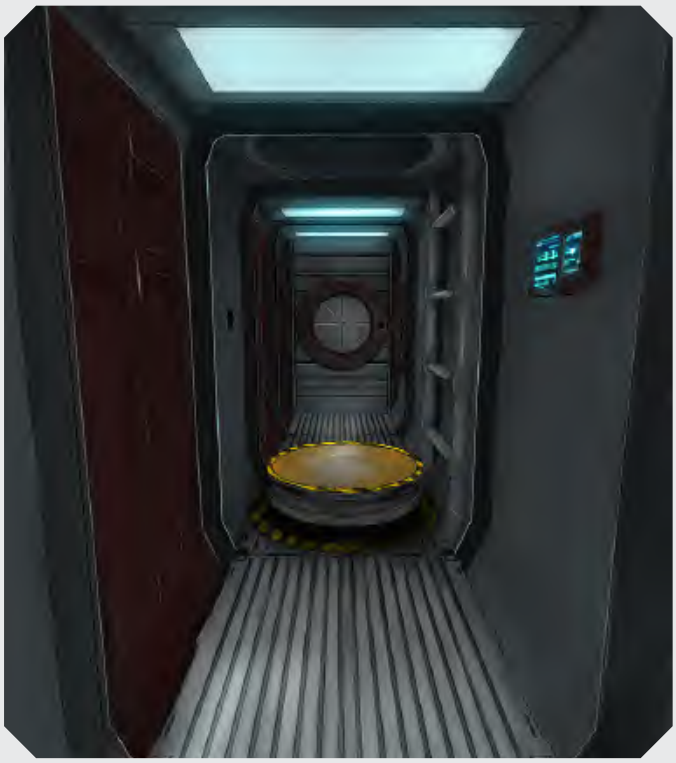
The *Animal*'s lift is in a somewhat awkward position, being in the corridor running between the main airlock and the rest of the ship. Although this can prove inconvenient for someone wanting to enter or leave the ship while the lift is in operation, it does serve an important role; the *Animal*'s bridge is on the upper deck, so a lift must be positioned close to the entrance in order to facilitate quick boarding. Both ladder and lift are overbuilt, as the *Animal*'s included air/raft may be used to transport anything from hunted game to traded cargo, which must then be passed down into the cargo bay on the lower deck.

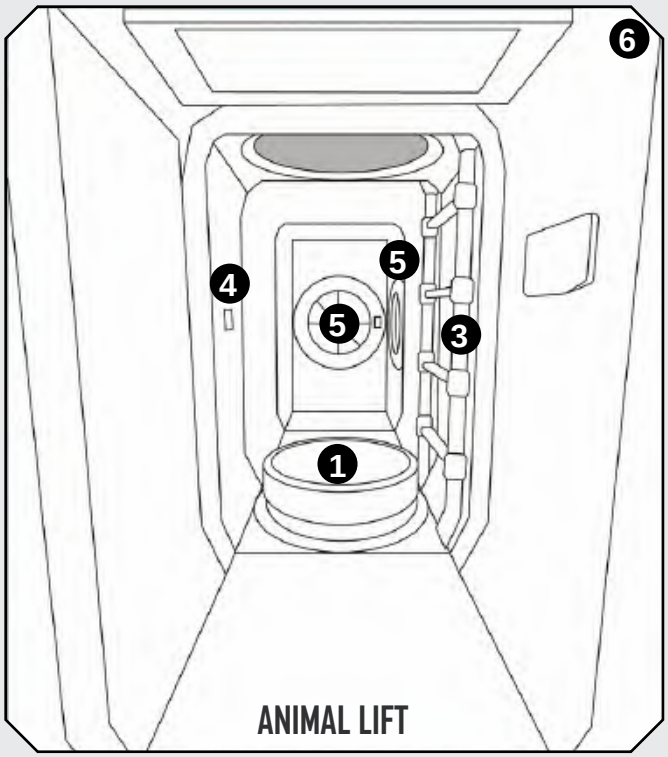
The *Suleiman* has a barrier around the base of the lift to keep loose cargo from accidentally falling under the platform during transit. There are sensors under the lift platform for such problems that will halt it if anything is under the plate, usually moving a short way to allow inconvenient access rather than no access. Be sure to check the security camera if a lift is malfunctioning, as there may be something blocking the lift on the floor below. Moving obstructions can prove complicated, which provides a good use-case for remote-controlled grav carts.

Both the *Animal* and *Suleiman* have a separate ladder/lift providing access to their turret, a common arrangement for roof-mounted turrets. These lifts are frequently set to rise quickly due to the urgency of reaching the turret when under attack.

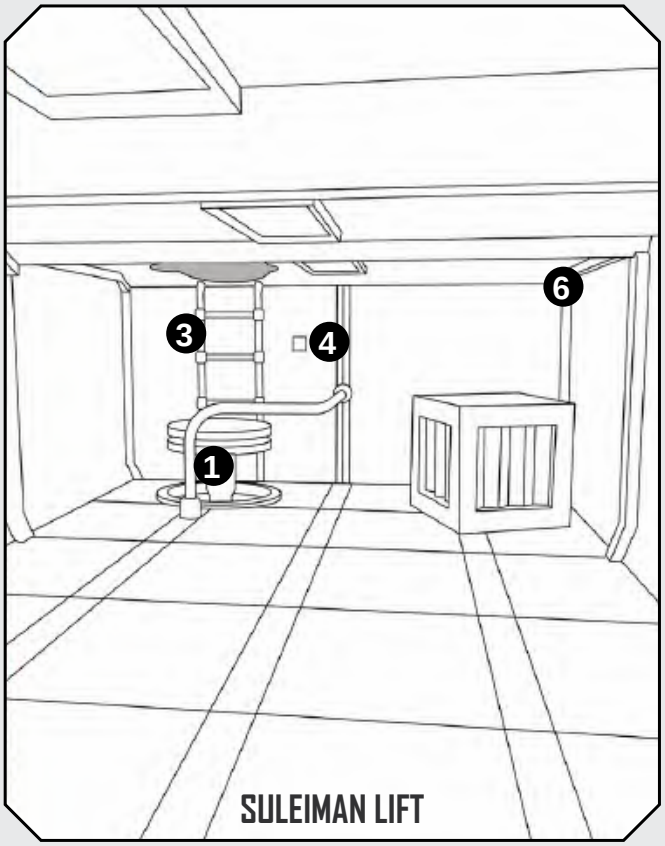
The *Empress Marava* has a similar issue to the *Animal*, being located in the middle of not only a corridor but an intersection. This exacerbates the issue of someone trying to traverse the corridors while the lift is in use but has proved useful for quick access regardless of where someone is on the fore end of the lower deck. However, it may have been this issue that led to the crew of our example – the *Gustus* – opting to remove the gravitic lift's platform, leaving only a lighted ring where the grav-plate is engaged. The platform's removal can make traversal easier, albeit at a risk of walking into a still-active lift but limits what can be carried between decks.

1. Lift platform (Animal and Suleiman only)
2. Gravitic lift (Empress Marava only)
3. Emergency ladder
4. Lift mechanism
5. Iris valve
6. Security camera and fire suppression projector

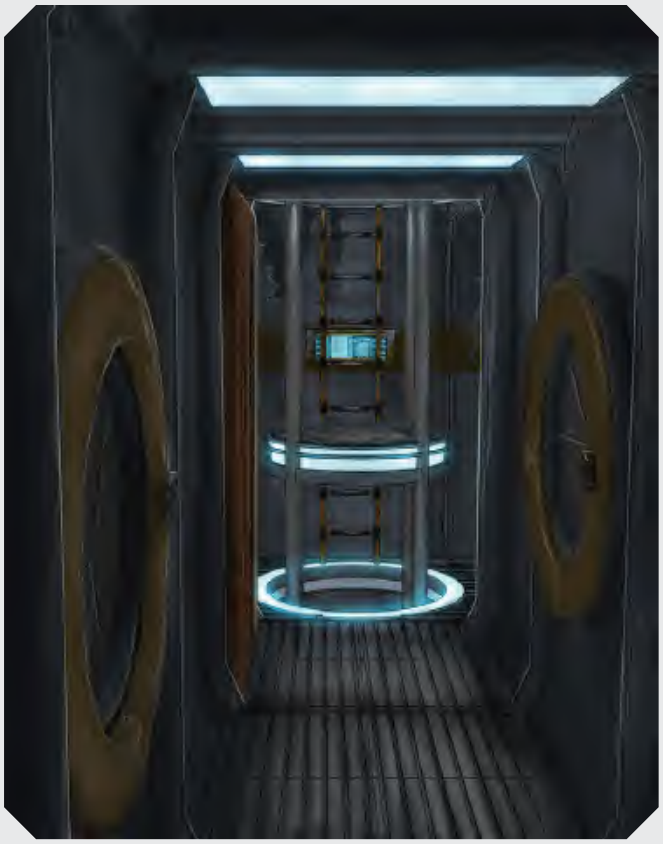


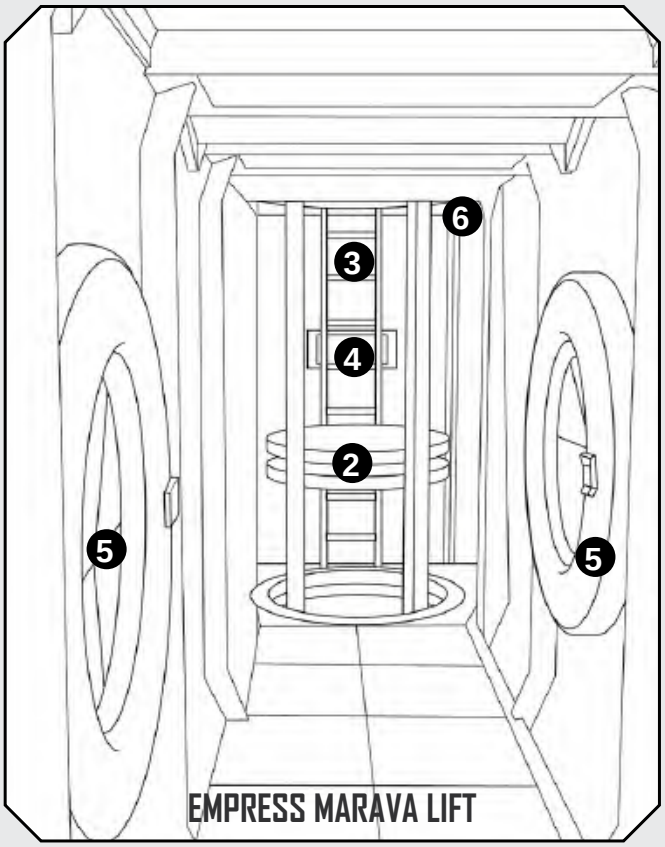


ANIMAL LIFT



SULEIMAN LIFT





EMPRESS MARAVA LIFT

5. STATEROOM

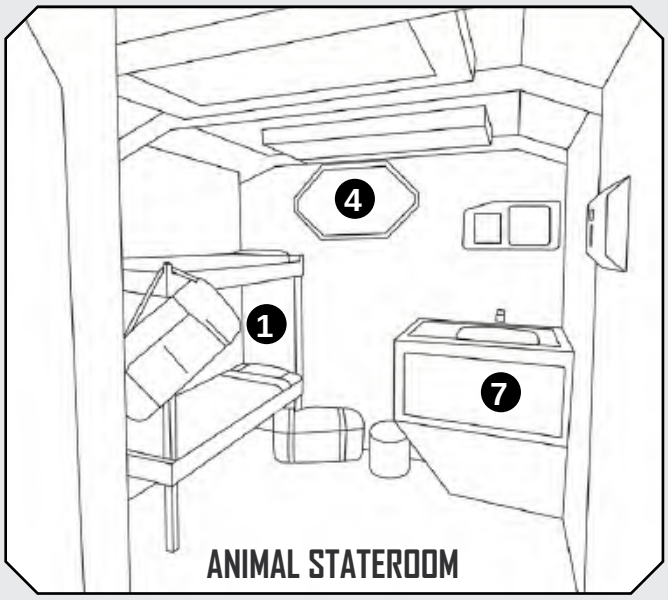
A sophont's stateroom is their corner of the ship, even if shared. It is where crew can relax, store personal items, sleep and generally live. As with any personalised space, a stateroom is a reflection of its inhabitant and as such will be as varied as the sophonts who live in them, as some may also use their room as a place of study, private meditation or worship. Some are messy while others are spotless. This section concerns itself with how staterooms are utilised aboard each of the three example ships and how their crews have modified them.

The *Animal*, as with many passenger-carrying ships, makes some attempt to divide crew staterooms from passenger's staterooms. In this case, the four staterooms on the port side of the upper deck are generally reserved for crew, as they are positioned closest to restricted crew areas. The remaining staterooms are more suited to passengers, as the three on the starboard side are located close to the ship's common area and the four on the lower deck are in proximity to the trophy lounge. As the *Finicky Platypus* is typically used for hunting expeditions, the pictured stateroom features a selection of hunting equipment. In addition, the crew selected a steam-based shower, as both water and sonic variants have proved less efficient at removing blood from clothing and skin.

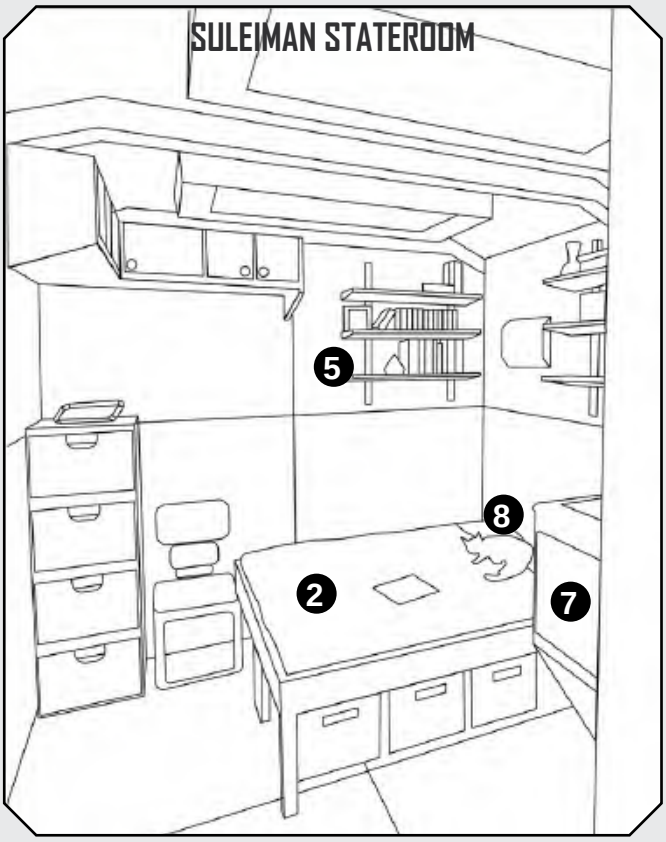
The *Suleiman*, despite being rated for three crew and often carrying two, is built with four staterooms. The *Suleiman* is intended to run courier missions but these do not always involve traditional cargo. Often, a number of passengers must be carried, some of whom may baulk at double occupancy. As a result, four staterooms are present, although one can be co-opted as a common area. In the case of the *Dark Poni*, only one of the four staterooms is routinely occupied by the crew. The IISS generally prefers sonic showers, as this offers the best cleaning ability across the widest range of contaminants.

The *Empress Marava* has perhaps the most dramatic example of segregating passengers from crew, as the six passenger staterooms and their common area are located on the upper deck, completely separate from both crew staterooms and essential systems. The *Gustus*, however, carries five crew with enough diversity that double-occupancy is infeasible, causing one passenger stateroom to be used by crew. It is because of this diversity that a water-based shower was chosen; both steam and sonic showers can be irritating to certain sophonts' physiologies. The pictured stateroom belongs to the astrogator.

1. Bunk bed (Animal only)
2. Double bed (Suleiman only)
3. Single bed (Empress Marava only)
4. Gun rack (Animal only)
5. Shelves (Suleiman only)
6. Knickknack shelves (Empress Marava only)
7. Foldable washbasin
8. Ship's cat



ANIMAL STATEROOM


SULEIMAN STATEROOM
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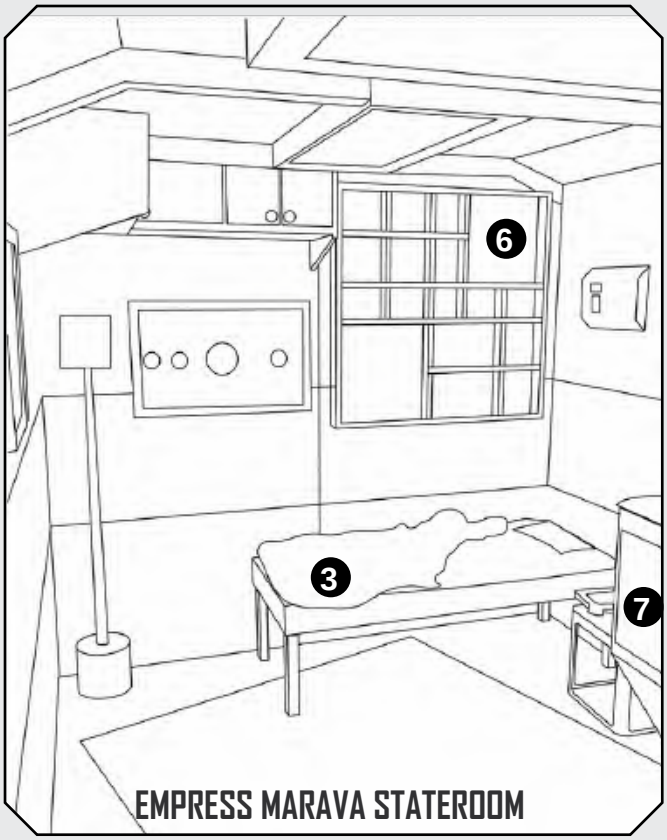
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7
EMPRESS MARAVA STATEROOM

6. DOCKING SPACE

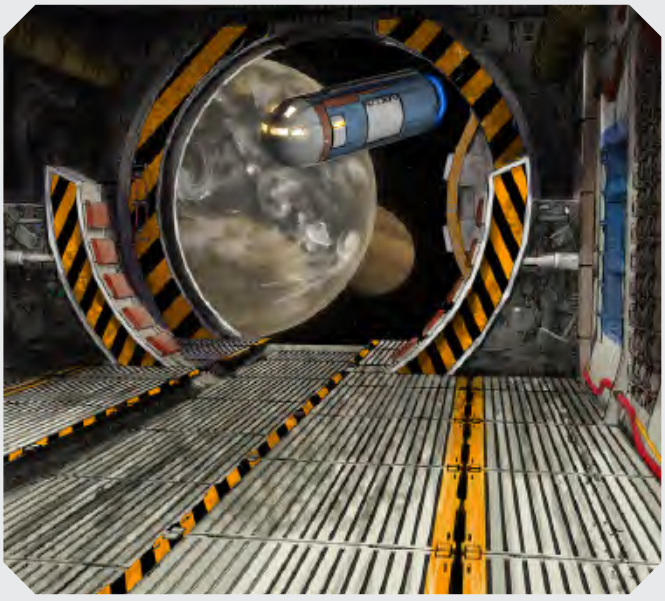
Many popular small ships are designed with an exploratory vessel separate from the main ship and these examples are no exception. All three have a docking space for an air/raft; the *Animal* has an additional docking space for a launch, while the *Suleiman* carries disposable probes.

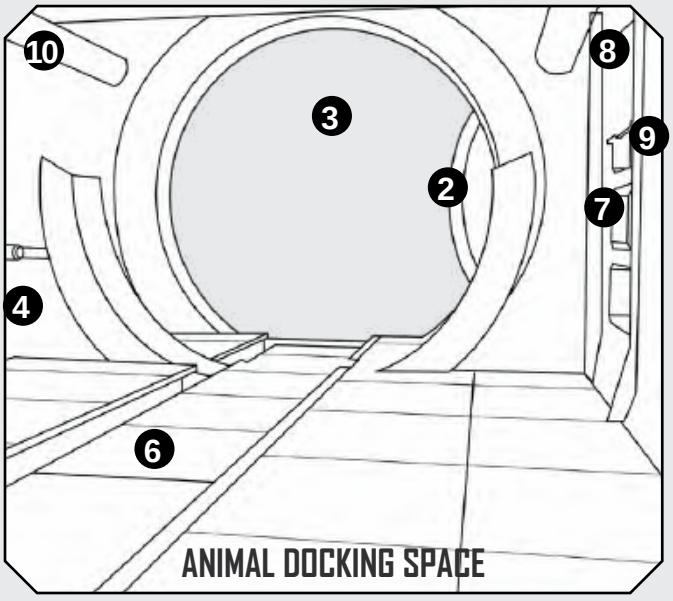
The *Animal* is likely the most interesting, courtesy of the aforementioned launch. Fitting a relatively large craft on a small ship resulted in a number of compromises; for one, the launch carries an ATV, causing maintenance to become even more complicated. With no way to remove the ATV from the launch while docked, any tools or spare parts must first be brought into the docking space, then into the launch and then the ATV's hangar. Repairs are typically delayed until the launch can be moved outside, usually at a starport with adequate facilities. Comparatively, the air/raft dock is a much simpler affair, consisting of a sliding door on the dorsal side of the ship. However, its location just behind the *Animal*'s turret can make docking while in combat complicated.

The *Suleiman*'s air/raft docking bay – other than its position next to a workshop, making maintenance much easier – is largely identical to the *Animal*'s, including proximity to a dorsal turret. It is, however, unique in that it carries a number of probe drones. These are slightly distinct from vehicle docking bays, mostly in their means of access and, besides probe drones being much smaller, it is not unheard of for both deployment and retrieval to occur simultaneously. As a result, there will typically be two access hatches connecting to the same storage airlock. One will be a small-scale launch tube, using either electromagnetic or gravitic propulsion, where the other will typically be a long docking arm to reach for and clamp to approaching drones.

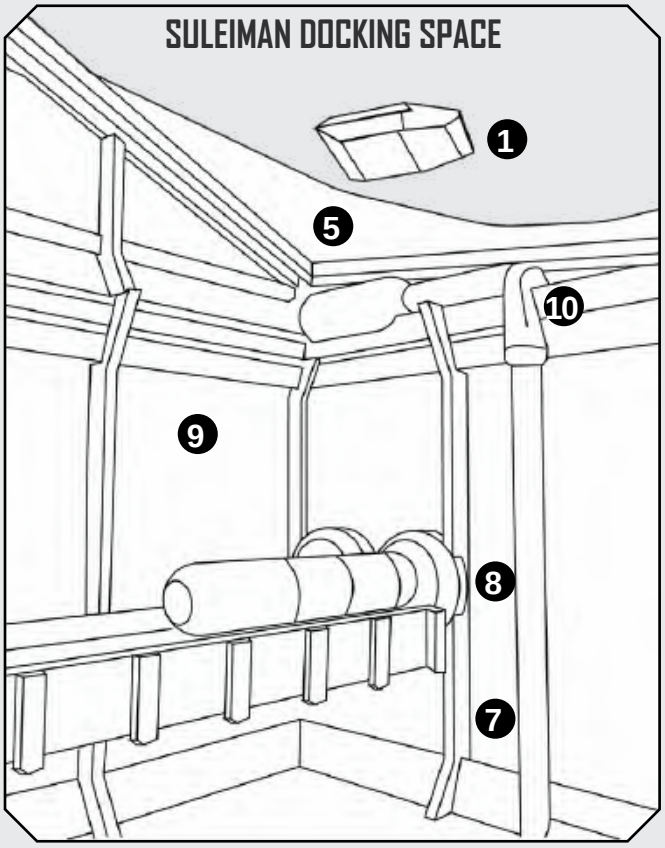
Unlike the *Animal* and *Suleiman*, the *Empress Marava* allows its air/raft to be docked through a front-facing docking space on the lower deck, which means the air/raft can be docked in either nose-in or nose-out orientation. Whichever is used depends on the pilot's preferences, many of whom are quick to defend them. Pilots that expect a stressful situation on landing will generally dock nose-out to facilitate rapid deployment, while those on ships with less exciting missions prefer the greater ease of docking nose-in.

1. Air/raft (Empress Marava and Suleiman)
2. Docking space hatch (Empress Marava and Animal)
3. Launch (Animal only)
4. Vehicle part storage
5. Overhead docking space hatch (Suleiman only)
6. Docking clamps
7. Decontamination scanner
8. Decontamination projector
9. Vent for air filtration and pump
10. Security camera and fire suppression projector





ANIMAL DOCKING SPACE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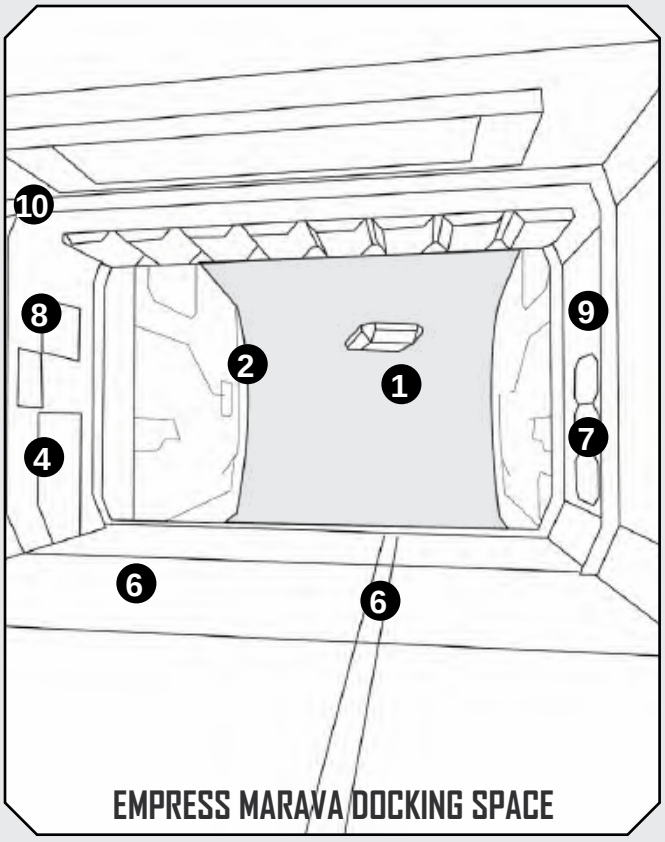
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EMPRESS MARAVA DOCKING SPACE

7. AIRLOCK

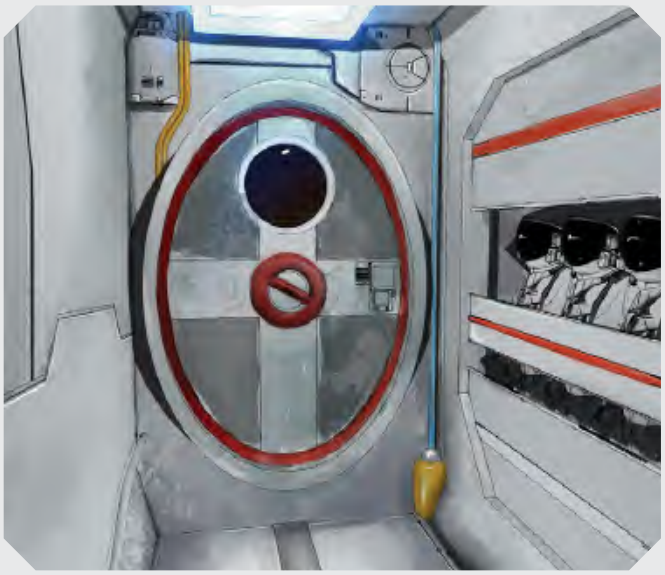
The basic airlock is among the least variable internal locations between ship classes, having long since been standardised. It has performed a studied and refined vital function since the earliest days of spaceflight and other applications that deal with significant pressure or environmental differentials.

In addition to a hatch, the Animal's airlock features a hinged floor that unfolds into a staircase. However, fitting this staircase into the considerably smaller airlock the Animal used proved complicated and required a retractable pad extending out of the floor plate. The airlock's smaller size limits what can be stored within, leading to the nearby ship's locker being co-opted to store additional equipment.

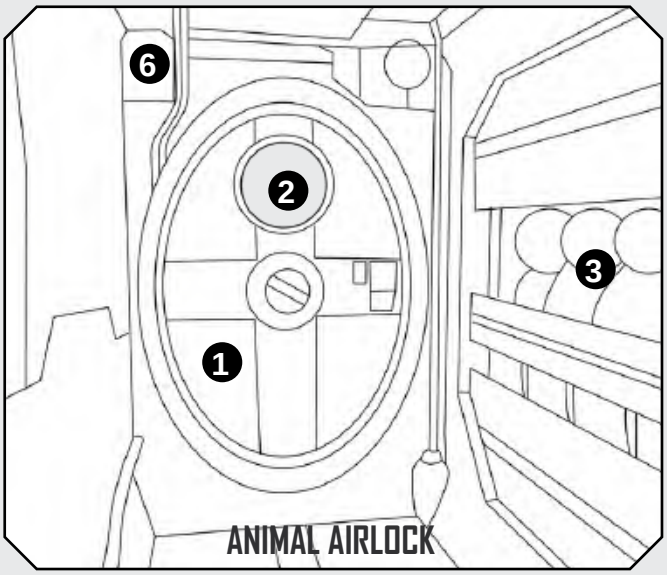
The *Suleiman*, as it does not need to contend with much in the way of heavy cargoes, opted for a much simpler approach; keep the hatch and add an external ladder to provide access to the ground. It is much larger than the *Animal*'s airlock, allowing more room for vacc suit storage.

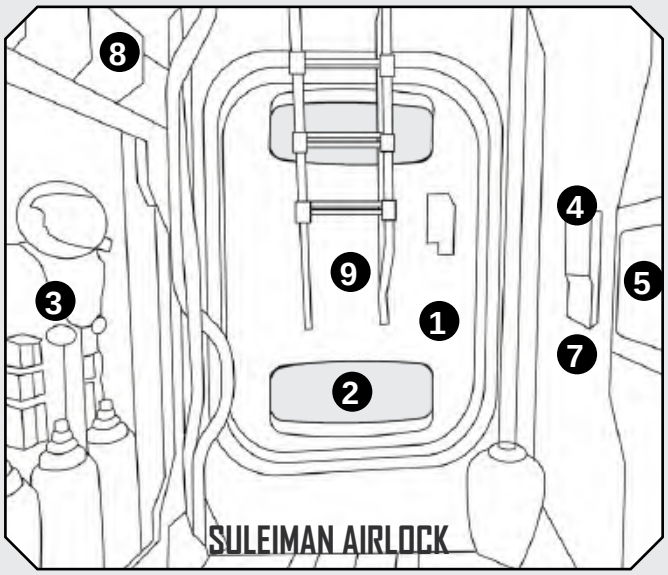
The *Empress Marava*'s personnel airlocks are largely identical to the *Suleiman*'s but its cargo airlocks deserve more notice. The external hatches match the standard size for a small cargo hatch, allowing Tonner cargo containers – see page 45 – and small vehicles to be loaded and unloaded in hostile conditions. This external hatch includes a cargo ramp to make loading easier, not to mention access to the onboard loading belt.

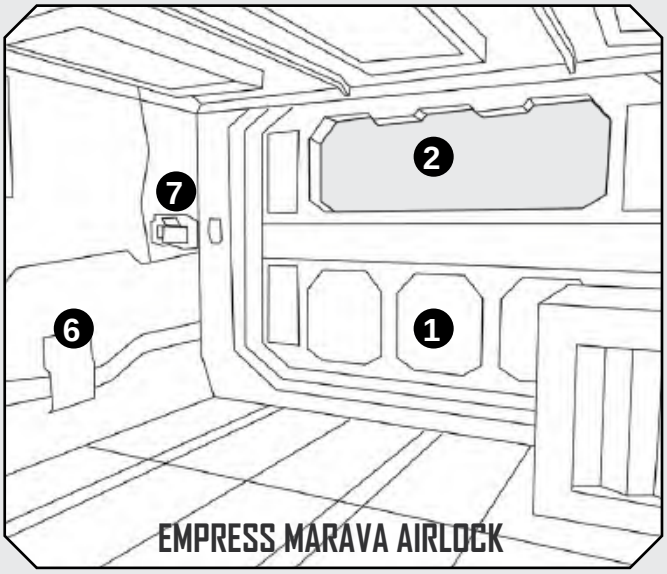
Not all entrances are airlocks. The rear cargo ramp of an *Empress Marava* is a prime example. Care must be taken when opening these away from port. The problems of opening in vacuum aside, doing so in a tainted atmosphere brings the taint aboard, requiring decontamination of exposed spaces.



1. Outer door
2. Outer window
3. Suit storage (Animal and Suleiman only)
4. Decontamination scanner
5. Decontamination projector
6. Vent for air filtration and pump
7. Control panel (pressurisation and decontamination controls)
8. Security camera and fire suppression projector
9. Ladder (retracted, Suleiman only)







8. POWER PLANT

In many ships within the Third Imperium, particularly smaller ones, the power plant, jump drive and manoeuvre drives are co-located in the engineering section, for the sake of convenience. As the manoeuvre drive is traditionally aft, this places the jump drive and power plant there too. Note that a great deal of tradition is involved here, as there is no one place aboard a ship that the power plant must be.

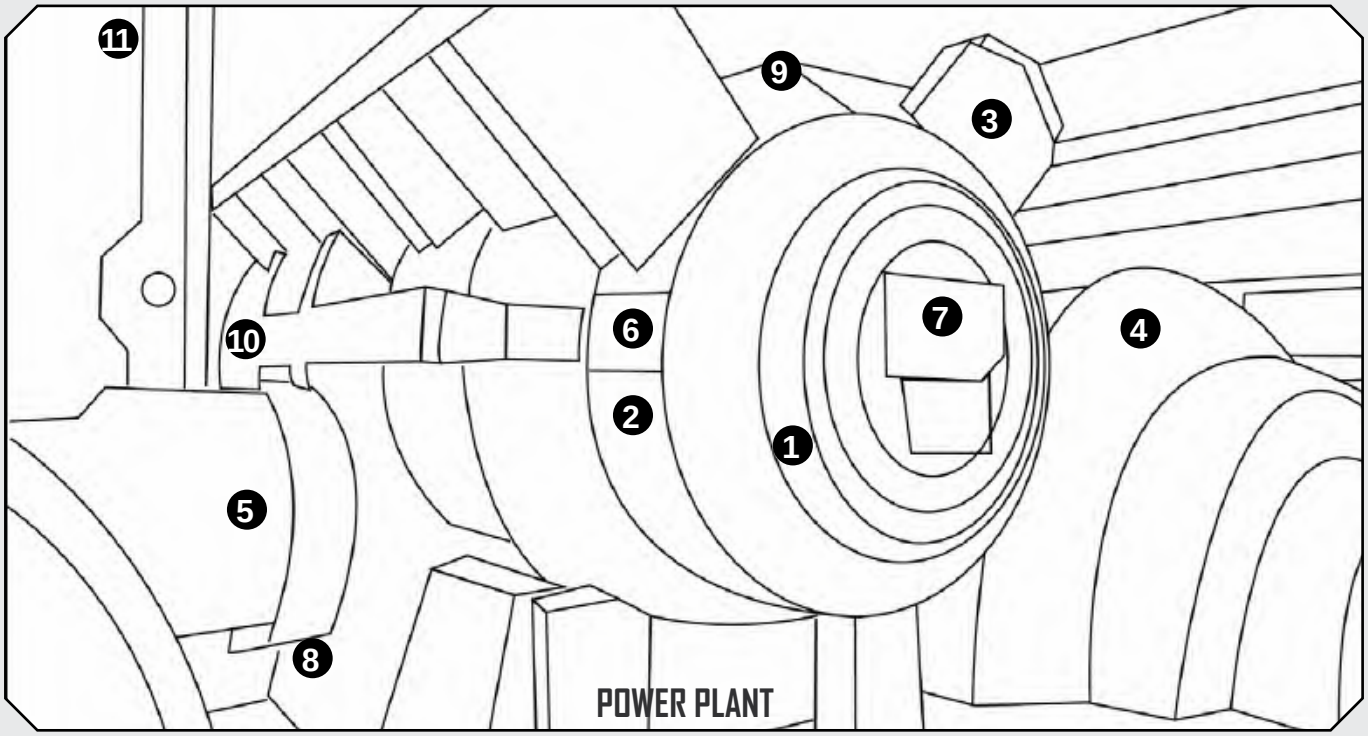
The *Animal*'s power needs, greater than the other two vessels, demanded a compromise between two schools of thought within naval architecture; whether it is better to use an array of individual cells or combine them into one larger power plant. It carries two individual power plants, either one of which is sufficient to run the ship's essential systems, which when combined can run most of the ship's systems simultaneously, allowing either to be turned offline for maintenance or repair without putting crew at risk. The corridor between these two plants allows easy access to either, rendering maintenance significantly easier but their close proximity can result in one hit disabling both.

The *Suleiman*, perhaps as a result of Vilani influence, echoes the original Fusion+ design. All individual cells are concentrated into a single plant, leading to an appearance not entirely dissimilar to internal combustion engines. Although this resulted in impressive redundancy and ease of maintenance, it lacks something in capacity. Should the manoeuvre and jump drive be used at full draw at the same time, essential ship systems must be throttled, including sensors and weapons. This is rarely a severe problem but is enough of one that some crews have opted to install high-efficiency power cells to charge the jump drive instead of relying on the power plant.

The *Empress Marava*'s power plant resembles the *Animal*'s, despite its much lower power demands. It is likewise divided into two but they are located in disparate locations to port and starboard. This was likely done to accommodate larger cargoes but also allows for greater survivability. However, the limited power generation of each can handle little more than basic life support, so any crew anticipating meaningful combat would be well-advised to upgrade them.

1. Reaction tank
2. Gravitic containment plates
3. Nuclear damper nodes
4. Power storage block
5. Fuel injectors

6. Plasma monitors
7. Control computer
8. Fuel pipes
9. Power cables
10. Helium exhaust
11. Security camera and fire suppression projector



9. MANOEUVRE DRIVE

Essentially a set of high-powered grav plates stacked in sequence, the manoeuvre drive is the technology that enables economical intrasystem travel and is among the first applications of gravitics. As detailed in Manoeuvre Drives starting on page 77, a manoeuvre drive does not just provide thrust but directional control, with more agility the more the m-drive units are spread out. The three example ships illustrate this.

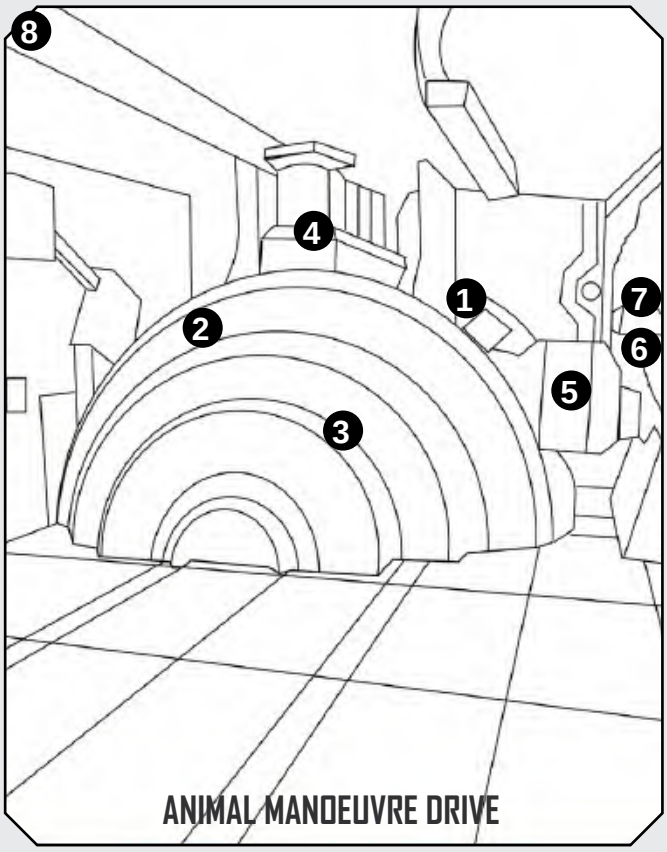
The *Animal* is an oddity; unlike other examples, it mounts only one manoeuvre drive, with just one thruster plate. Based on design records, it is believed this was done to avoid interference with the multi-environment spaces, as gravitic fields could react poorly with alien life carried aboard. As a result, it is the only one to carry a manoeuvre drive capable of independent thrust vectors from the same thruster plate.

The *Suleiman*, optimised for ease of maintenance over agility, mounts twin manoeuvre drives that share a single power distributor. The drives being close together lowers manoeuvrability but this setup provides one less component to maintain. This can limit potential for upgrades in future, as a new power distributor would be needed to handle the higher power demands of a 3G or greater drive.

The *Empress Marava* mounts two independent manoeuvre drives with two power distributors, designed for a wider variety of missions and intended to offer wider possibilities for upgrades. These are mounted further apart, granting better agility, although this was done to accommodate larger cargoes through the rear door rather than concern for performance in a dogfight.

Like the jump drive, the manoeuvre drive is not the most visually spectacular of ship systems; it pulls energy in and outputs a different form of energy out without visible mechanical motion. As with the other large machinery in the engineering section, the average visitor will see nothing but large metal boxes, power cables, screens with status updates and security cameras with fire suppression projectors. Once outside the ship, however, the sight of a powerful manoeuvre drive in operation can be an awe-inspiring sight.

1. Thruster plates
2. Power distribution system
3. Cooling system
4. Bracing
5. Input power cables
6. Drive control computers
7. Status monitors
8. Security camera and fire suppression projector



ANIMAL MANOEUVRE DRIVE

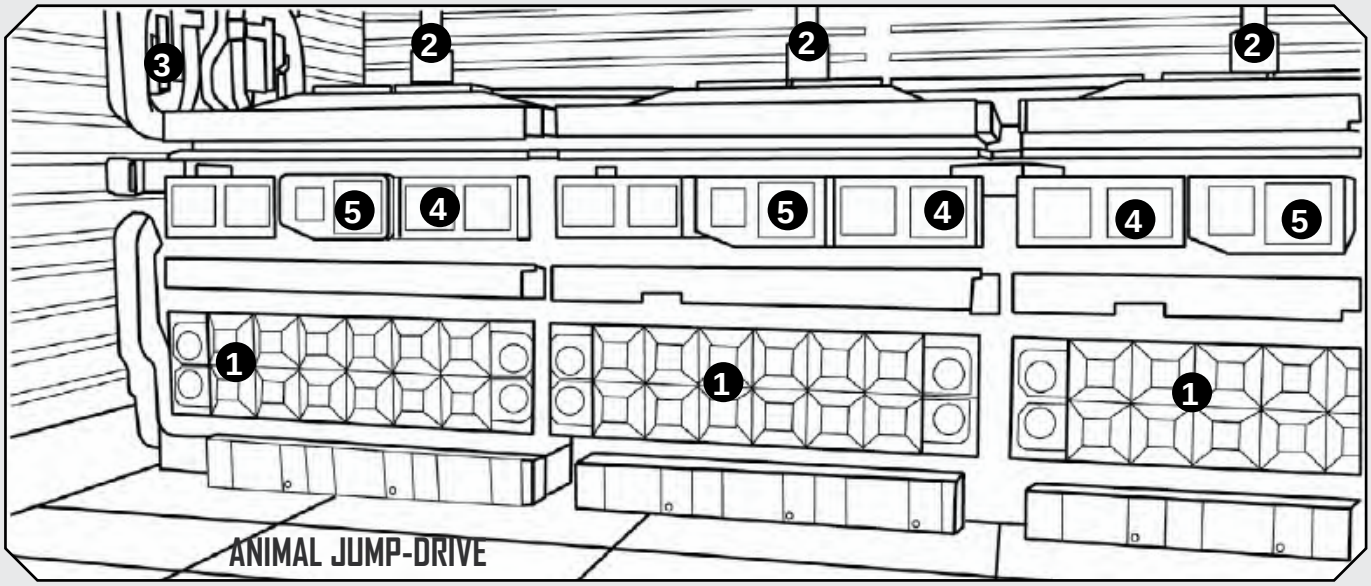
10. JUMP DRIVE

As any starship crew knows, the 'jump drive' extends beyond the central unit shown on deckplans out across a ship's hull; the many emitters that propel a ship into jumpspace, and in grid-type drives the jump grid. In this way, the entire outer hull could be considered the 'jump drive'. The central unit is mainly energy storage and distribution system, with dedicated computers, and in bubble-type drives the lanthanum alloy core of the drive/shunt system.

To an untrained eye, the drive on a naval jump-6 courier and the jump-1 drive aboard a *Beowulf* free trader may look almost identical, aside from their bulk.

An engineer may notice more robust power conduits, greater density of jump emitters or higher-grade zuchai crystals but none of these are particularly noteworthy. As a result, the jump drives on our three example ships are largely identical.

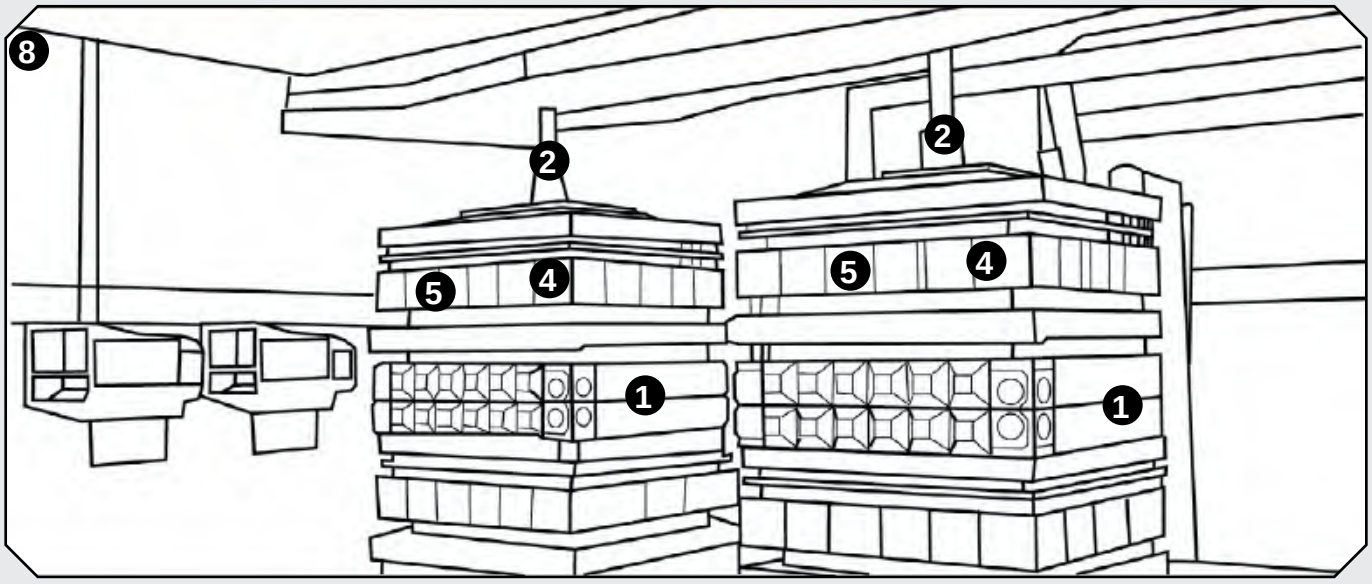
1. Zuchai crystal array
2. Power input
3. Power output
4. Jump computer
5. Status monitors
6. Security camera and fire suppression projector



ANIMAL JUMP-DRIVE

ALTERNATIVE JUMP-DRIVE DESIGN

ALTERNATIVE JUMP-DRIVE DESIGN



11. CARGO HOLD

Certain naval architects, chiefly those who have never served aboard a spacecraft, dismiss the cargo hold as leftover space, to be listed on a specifications sheet and forgotten about. They are mistaken. It is the stowage space for crew supplies and spare parts, directly affecting ship endurance; the lifeblood of any merchant vessel, the modular part of any spacecraft and so much more.

The *Animal*'s cargo hold is a cubbyhole with no external access. Nothing gets in or out unless it can fit through an iris valve. This is tolerated because the hold is mainly used for implements, supplies and prizes not important enough to display, all of which can be carried by hand. Refrigerated and other special-environment cargo space is supplied by the multi-environment holding tanks, leaving the hold free for room-temperature cargoes.

The *Suleiman*'s cargo hold is similar, although can be accessed from above. It is common to place cargoes on hovering or wheeled cargo trolleys that can fit through the iris valve, ride the lift down, and be pushed into the bay. The version presented here has a flat floor cargo hold.

The *Empress Marava*'s cargo hold is the main purpose of the ship and it shows. Aside from the greater volume, there are airlocks of substantial size with large access hatches to permit transit of containers, allowing it to take on and drop off 4Ds, Tonners and smaller containers even in vacuum or hostile atmospheres. The two cargo airlocks open onto the middle of the hold for redundancy as well as to speed up loading and unloading, so important cargo can be stowed to one side while maintaining access to the other. A common customisation is to remove the staterooms adjacent to the cargo hold, using the space for additional capacity.

1. Cargo area
2. Lift (Suleiman only)
3. Small cargoes on trolleys
4. Preserved prize carcasses (Animal only)
5. Cargo airlock doors (Empress Marava only)
6. Tonner cargo containers (Empress Marava only)
7. Cold storage (Suleiman and Empress Marava only)
8. Food
9. Spare parts for ship maintenance
10 Control panel (environment, alarms and fire extinguisher)
11. Security camera and fire suppression projector

CARGO HOLD

12. FUEL PROCESSOR

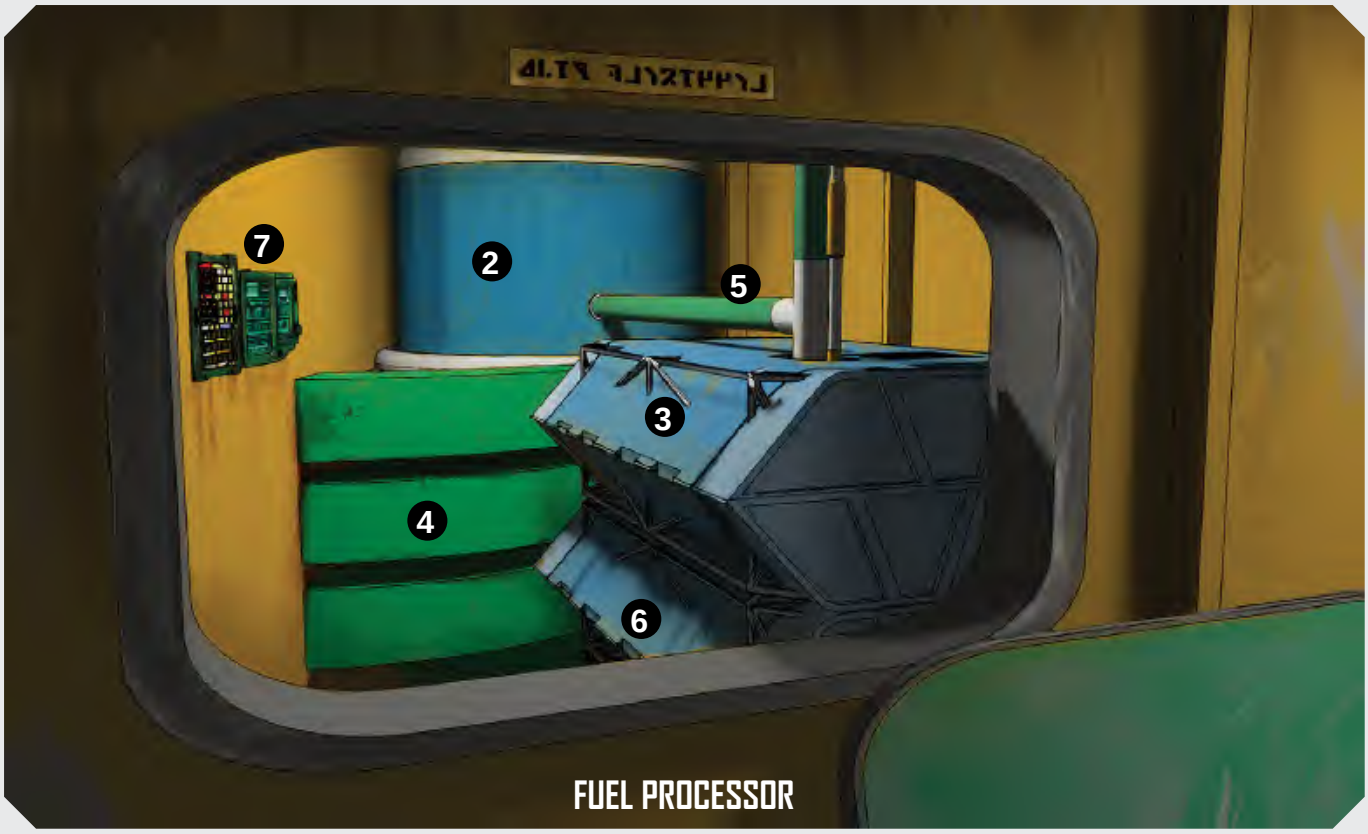
Fuel scoops and processors greatly extend operational range, as they allow a ship to jump without relying on infrastructure or devoting more internal volume to fuel. They are often tucked away behind access panels rather than given a dedicated room, as they are monitored remotely with internal mechanisms to diagnose and fix any issues. It is rare that an engineer must directly interact with these components.

The *Animal* is unique among the three examples, as it mounts its fuel processor in its own dedicated space, with a small area for an engineer to stand and work. However, as it is one contiguous unit, it lacks redundancy. In addition, as fuel for the *Animal* is stored in its wings, it takes longer on average to get to and from the processor than in the other two ships. It is common to process one wing's fuel tanks at a time, using internal baffles to push the fuel in a loop around the tank, with a fixed baffle near the pipes leading to and from the processor and a floating baffle further along the loop as more fuel is processed.

The *Suleiman* serves as a counterexample; its fuel processors are mounted in two separate units on the port and starboard sides, which maximises surface area and grants redundancy, and they feed directly into the two fuel tanks used for the jump drive. In addition, it can refine enough fuel for one full jump in 12 hours compared to both the *Animal*'s and *Empress Marava*'s 24. However, it also has worse access than either of the other ships, or – as some frustrated scouts claim – any ship that currently exists. A tight crawlspace must be traversed to reach them, the only access points to which are found in the bulkheads of staterooms. Maintenance via external access is common, although obviously problematic if done while underway.

The *Empress Marava* is a compromise between these two. Like the *Suleiman*, it splits its fuel processors into two units and exposes them to the outer hull, where they have direct access to the single fuel tank the *Empress Marava* uses. Unlike the *Suleiman*, they are simple to access; their hatches can be found in the ceiling of the lower cargo deck, above a ladder to grant easy access.

1. Fuel scoop
2. Electrolysis, heating and gravitic sorting tanks
3. Filters
4. Fuel tank connection – unrefined fuel
5. Fuel tank connection – refined fuel
6. Impurities output
7. Status monitors



FUEL PROCESSOR

Although fuel scoops could be mounted on the dorsal side, as the processors can be found on the top deck, this is rarely done as the low pressure created during pitch-up manoeuvres would limit fuel intake.

13. TURRET

A minority of ships are designed expressly for combat but most come with hardpoints installed. Some are for the sake of combat, even for just token attempts at self-defence. Others use them for directional sensors or mining equipment, particularly laser drills. While hardpoints can mount a range of weapon configurations, by far the most common is the turret.

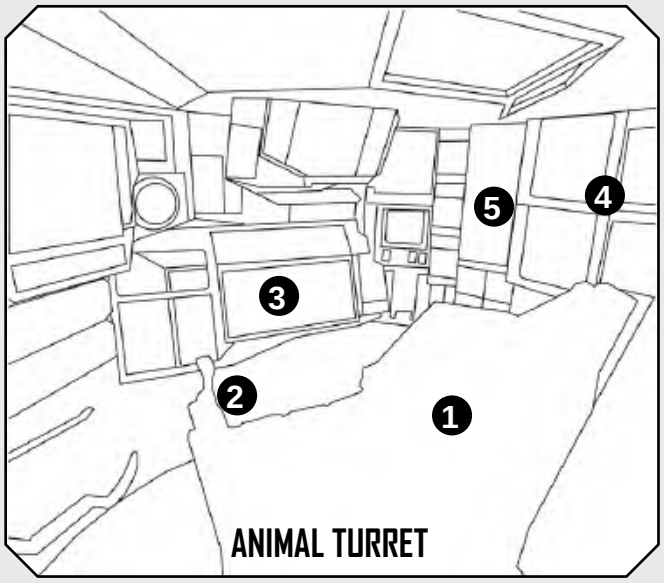
Instead of regular doors, iris valves are almost universally used for turret areas, even on many alien ships, for security and because turrets are often a focus of enemy fire. Most explosive items aboard a ship are found in the turrets, whether ammunition such as missiles or ultracapacitor banks for energy weapons. These items are usually kept on the turret's side of the partition to limit damage should they be set off.

As the *Animal* is intended for hunting expeditions, the mounting location of the turret has limited combat effectiveness. Although the dorsal side's centreline is an extremely common choice for single-turret ships, the *Animal*'s flat hull means the turret has limited depression, much to the dismay of those attempting to use ship-scale weapons to hunt or provide ground defence. Many who install a second weapon on their *Animal* do so on the ventral side to avoid this weakness. Gaining line of sight from the dorsal turret to ground targets requires either being at long range, tilting substantially, or flying inverted. As the *Animal* lacks lifters on its dorsal side, flying inverted is ill-advised but possible for those skilled enough. The *Finicky Platypus*'s pilot is quite practised at this manoeuvre and the ship mounts a pulse laser for use in taking down megafauna.

The *Suleiman* has a similar mounting location but, unlike the *Animal*, it is on a sharply angled hull. This allows the turret to be depressed to a much greater extent, allowing fire upon targets at almost point blank range while landed. The IISS installs weapons on their *Suleiman*s but they are expected to tackle such a range of missions that no single loadout would suffice. A missile rack might be installed for drone deployment, a mining laser for taking samples, a beam laser for self-defence and so on. As a result, a vessel will usually leave the shipyard with empty turrets for future modification. In addition, when a *Suleiman* is assigned for detached duty, all weapons are uninstalled by default. This is partly a cost-saving measure and partly to prevent crews – who still represent the IISS – from getting into trouble immediately. The *Dark Poni* featured here has a beam laser.

The *Empress Marava* has two turrets installed, one each on the port and starboard sides. This is a common choice for ships designed from the start to have two turrets, as opposed to retrofits like a two-turret *Animal*. They are mounted quite far forwards, which gives the *Empress Marava* good convergence of fire for a trader. The two turrets were also mounted in this way to provide cover for the cargo airlocks and to fend off pirates in space and displeased locals at port. The turrets are occupied by beam lasers out of the shipyard. This example, the *Gustus*, replaced its beam lasers with mining lasers, as some of its recent passenger service has been belt mining expeditions for those who have never been offworld.

1. Gunner's seat
2. Control grip
3. Primary display
4. Customisation controls
5. Ultracapacitor banks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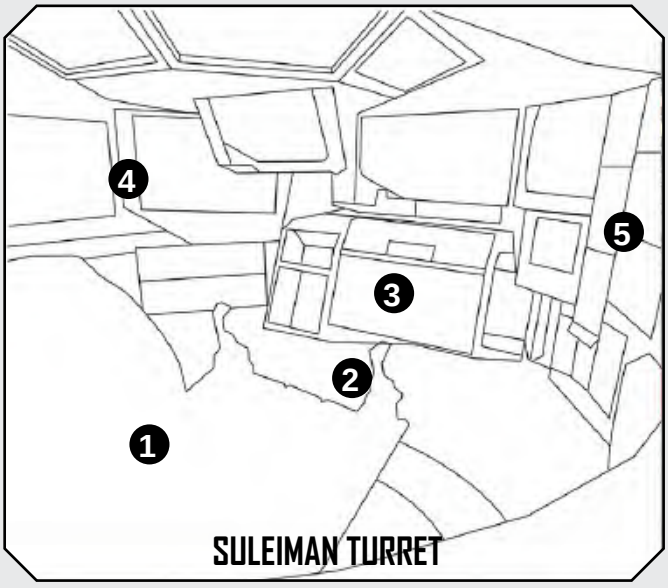
ANIMAL TURRET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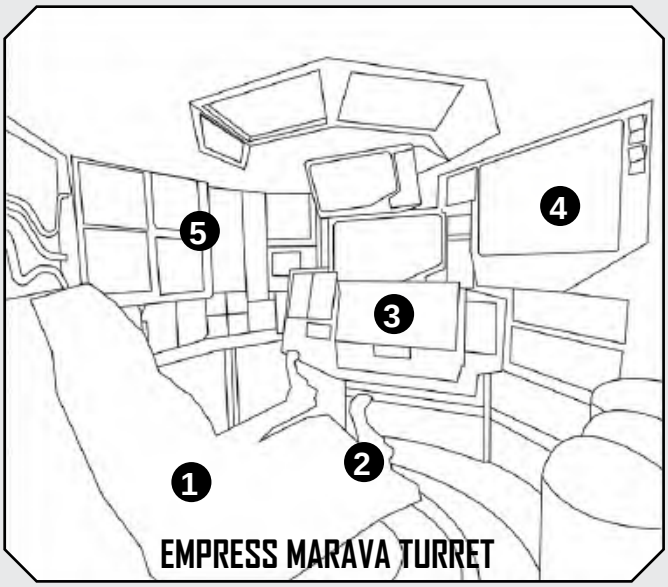
SULEIMAN TURRET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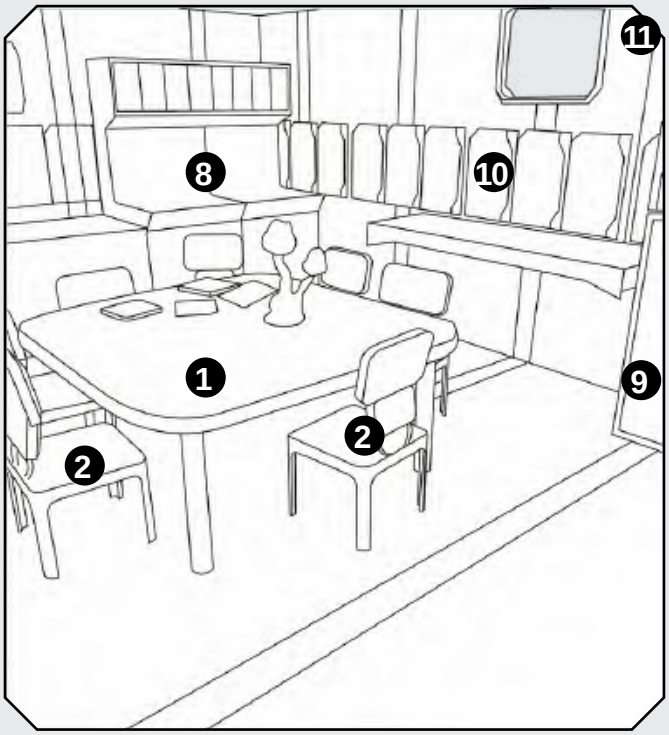
EMPRESS MARAVA TURRET

14. COMMONS

This area is designed to be an area of use to the entire crew. When exactly it is used depends on the crewmembers; some eat in alternating shifts and devote more space to teambuilding exercises and entertainment, while others prefer teambuilding by assembling the entire crew for meals. Fresh from the shipyard, a ship's commons typically has a galley, tables, chairs and a small storage area for food supplies, equipment or games, although this is inevitably modified before long. For smaller ships, a compact laundrette may be placed in a hideaway corner of the commons.

The *Animal* allots more room to the galley and food preparation area than most similarly sized ships due to its need to manually process fresh, exotic and possibly poisonous flora and fauna. Although the standard design from the shipyard does not contain a full-fledged gourmet kitchen, many owners install one at the first opportunity. The tables and chairs are situated where one can address the entire group from a single point in the room.

Whether or not the *Animal*'s trophy lounge should be considered commons is a debate as old as the ship class, which shows no sign of being resolved any time soon. On the one hand, it is typically used to display the crew's or owner's achievements in hunting. On the other, it is a natural place for those aboard to congregate.



SULEIMAN COMMONS

1. Tables
2. Chairs
3. Entertainment area (Animal only)
4. Hanging pots and pans (Animal only)
5. Stove/ovens (Animal only)
6. Microwave (Empress Marava only)
7. Exercise area (Empress Marava only)
8. Storage
9. Food refrigeration unit
10. Food dispensers
11. Security camera and fire suppression projector

COMMON AREAS

This is usually an under-detailed area of the ship on standard deckplans, on purpose, as it is the most variable from ship to ship, customised to each crew's desires and adjustable based on the current mission. For example, around the time its crew was interviewed during production of this book, the commons on the *Finicky Platypus* had a large exercise area, both to entertain passengers and provide exercise for the crew who were accustomed to 1G. The ship was often carrying Vegan passengers at the time, so ship-wide gravity was set to their homeworld's 0.5G.

Ships such as the *Suleiman* do not have a set area for commons, requiring the crew to eat, train or assemble in other parts of the ship. The crew use facilities in individual staterooms or the mini-galley in the office to dispense food, while utilising the cargo bay for any serious movement training and the bridge for important assemblies. The two or three-person crews commonly found aboard a *Suleiman* leave one or two staterooms spare, which are co-opted as a general assembly area if not used for passengers.

The *Empress Marava*'s commons are intended for passenger use. While it does contain what could be considered a full galley, it specialises in making and dispensing food from pre-processed packets, thus needing less overall space for food prep, leaving the rest of the area for moveable tables, stackable chairs and options for passenger comfort.

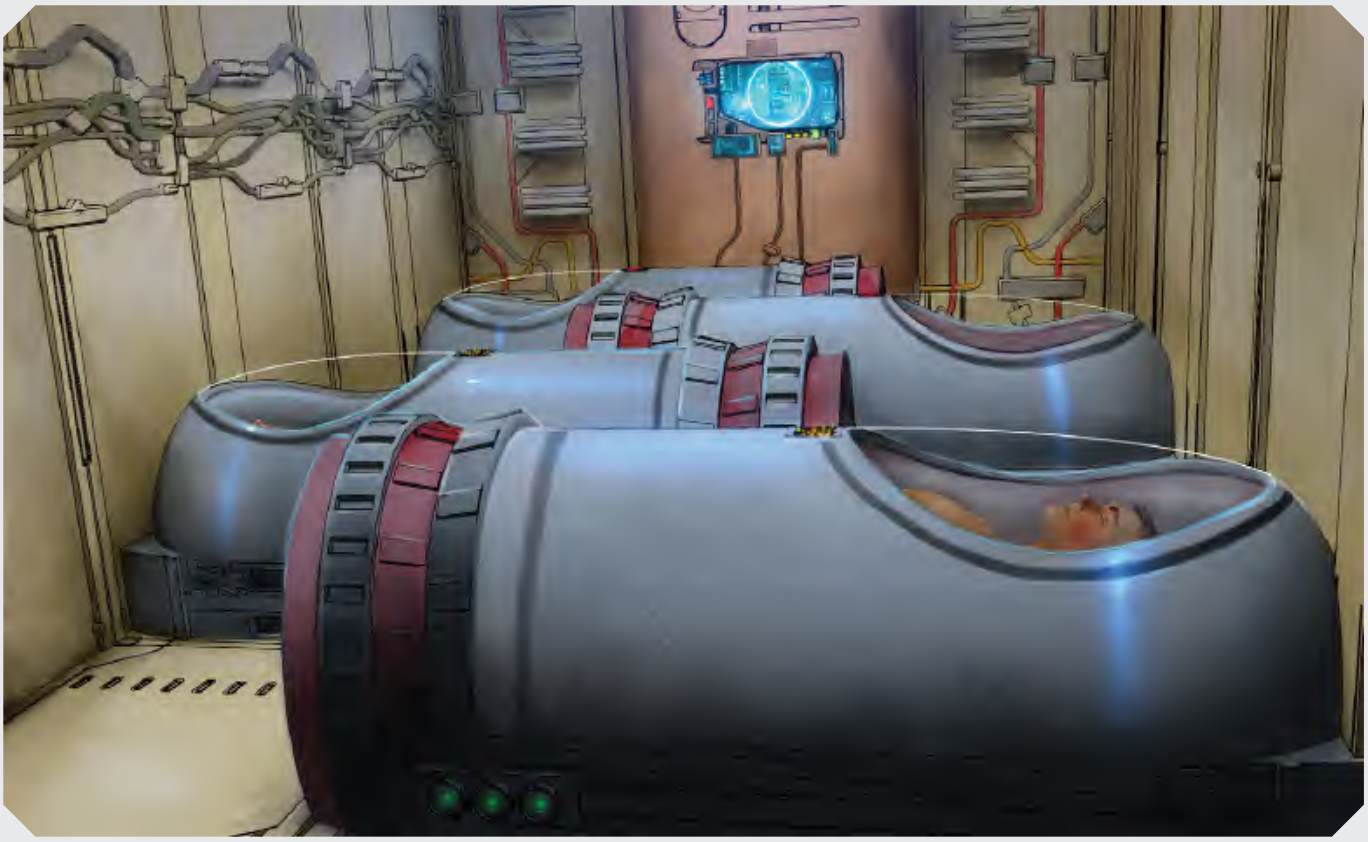
15. MISSION SUPPORT

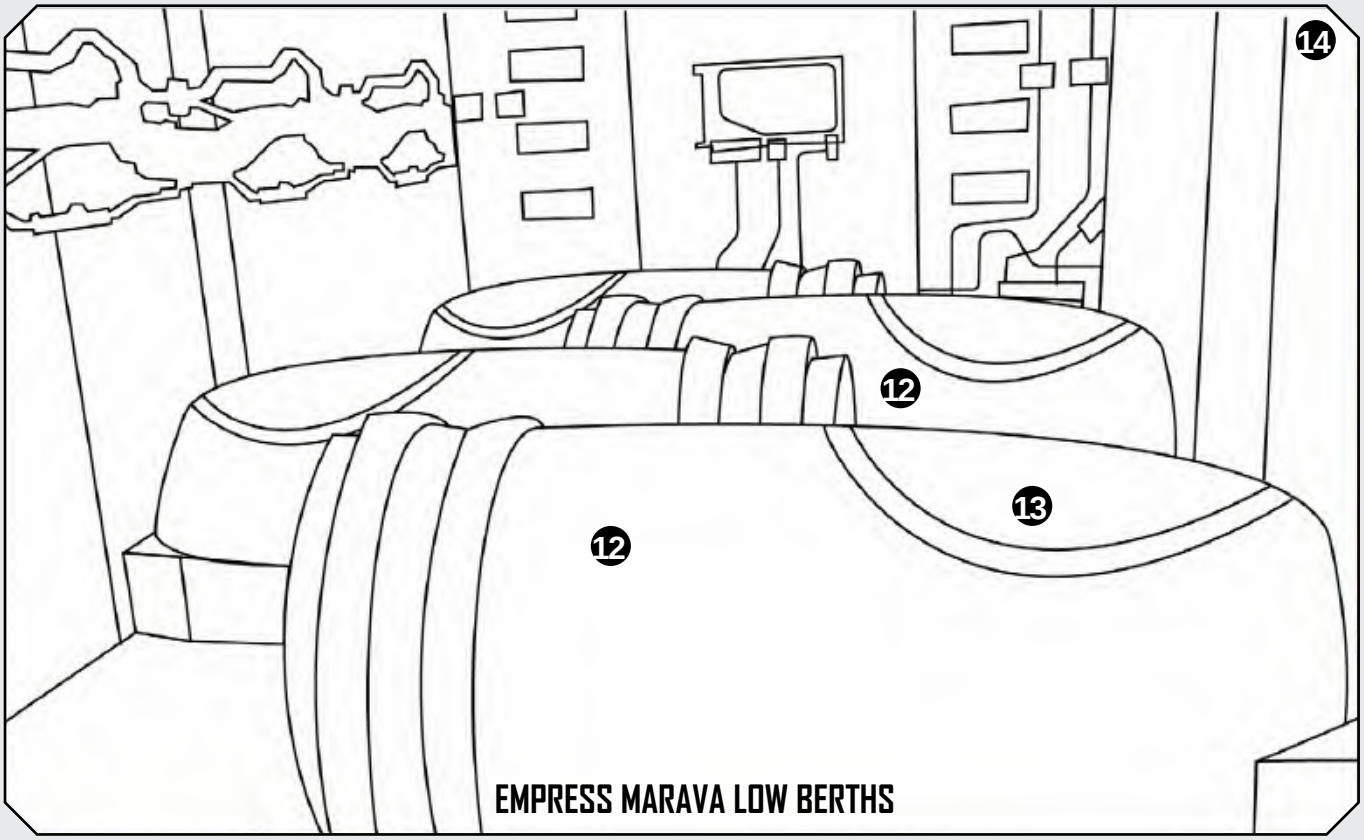
This section covers three areas dedicated to support of a ship's mission; the *Animal*'s multi-environment holding tanks, the *Suleiman*'s workshop, and the *Empress Marava*'s low berths. 'Mission support area' is a general term which can be applied to virtually any ship component, such as a passenger liner's commons or an assault ship's armoury but they will always be there.

The *Animal*'s multi-environment holding tanks are one of the most versatile areas within the ship. Most safari ships use these for live animals, as either trophies or bait for megafauna. The tanks can be adjusted to simulate an animal's native environment and can even house aquatic species by sealing the door and flooding the tank. A few captains have adapted them into brigs. Hunters have utilised the tanks for cold storage of freshly killed meat, which is one of their more pedestrian uses.

A workshop like the *Suleiman*'s can be vital for survival away from civilisation. Usually sized for two engineers, this room at minimum has a workbench with built-in tools. Computer-controlled vices with hand and power tools have organisation, storage and recharging stations built in. A simple gravity hammer wired to the ship's power, both to simplify its design and make sure it does not leave the room is a visually prominent addition. A fabricator cabinet with a 1x0.5x0.2 metre internal chamber for manufacturing small parts and electronics is standard, and a CNC machine with advanced TL tools such as a gravitic welder for reductive manufacturing works in tandem with a holographic design station that doubles as a console to control the workshop's automation. Other ship-specific equipment for the repair and fabrication of vital components, most often diagnostic equipment for electronic or mechanical faults, typically fill up the rest of the workbench and room. Stock *Suleimans* come with air filtration systems of notoriously limited endurance, building up intolerable smells over a month if the filters are not replaced weekly. This was standard to the point that spare filter supply was a common measure of a *Suleiman*'s endurance until someone hit on the trick of breaking down and remanufacturing used filters in the workshop, largely eliminating this need. Many *Suleiman* crews remain unaware that this is possible, let alone the steps involved, giving the ship class a reputation for smelly interiors.

For some sophonts, paying for space travel in a comfortable stateroom is too expensive, yet they need to travel from world to world. Low berths provide the cheapest way to see the stars. Ideally, a passenger will be placed in suspended animation before the ship takes off and not wake until they reach their destination. Despite some issues with surviving the trip if the ship is not properly equipped, for most sophonts this is the cheapest option to travel to other systems.





EMPRESS MARAVA LOW BERTHS

1. Empty tank (Animal only)
2. Live capture tank (Animal only)
3. Frozen meat (Animal only)
4. Storage areas (Animal only)
5. Control panel (Animal only)
6. Access panel (Animal only)
7. Fabricator cabinet (Suleiman only)
8. Wired gravity hammer (Suleiman only)
9. Tool cabinet (Suleiman only)
10. Holographic design station (Suleiman only)
11. CNC machine (Suleiman only)
12. Low Berths (Empress Marava only)
13. Passengers (Empress Marava only)
14. Security camera and fire suppression projector

16. LANDING GEAR AND LIFTERS

These systems rarely appear on deckplans but are essential all the same. Lifters can cover the entire ventral surface of the ship, while landing gear struts are often mounted at the corners. Among the three example ships, despite similarities in function between different landing gear, there is some difference to be found.

The enclosure the landing gear retracts into is not 'inside' in all but the most technical sense. Few designs pressurise this space or provide access from inside, leaving maintenance to be performed while the ship is landed. Would-be stowaways hitching rides on landing gear typically wind up crushed or suffocated, should they survive long enough for the ship to leave the atmosphere. Anyone agile enough to avoid being crushed and with enough foresight and resources to wear a vacc suit usually has an easier time simply boarding the ship.

The *Animal*, although expected to land in rough terrain, is also meant to carry significant loads. This necessitates a compromise approach as complicated landing gear would better handle rough terrain but not bear as much load. As a result, the landing pads are relatively simple, which can limit versatility. However, it can still actuate these pads independently, which allow it to not only adapt to uneven terrain but also 'crouch' closer to the ground. This can ease loading of larger cargoes into the rear without need of a crane or gravitic assistance. The considerable wingspan of the *Animal* presented some difficulties as if the landing gear were mounted too far out, it could not land outside of flat ground but if they were mounted too far in, it could risk tipping. Thankfully, the outboard sections of the *Animal* proved lightweight enough that this was rarely a concern, the occasional megafaunal avian using them as a perch notwithstanding.

Despite the *Suleiman*'s much smaller size and expected load, it has quite possibly the most sophisticated landing gear of the three. Only the *Suleiman* is expected to deal with virtually any landing site across Charted Space. It mounts landing gear under each corner of the ship's triangular hull, as this maximises the base and renders tipping virtually impossible. On the landing pads, there are expandable panels to increase the surface area and thus decrease ground pressure, preventing sinking into muddy or unsteady ground. Unlike most landing gear that fold away when not in use, the *Suleiman* keeps the landing pad flat as it enters or leaves the craft. This, combined with a sophisticated platform on the pad itself, allows the ship to stay level on uneven terrain by independently retracting each landing gear and adjusting the pads. Its lifter array is notable for its relatively high strength.

The *Empress Marava*, although capable of operating beyond pre-prepared landing pads, does not expect to land in the wilderness in the same way as the *Animal* or *Suleiman*. As a result, its landing gear is optimised to handle the much higher loads that almost 60 displacement tons of cargo can bring to bear. This requires simplicity, as the more complicated actuated pads of the *Suleiman* or crouching ability of the *Animal* would impede its load-bearing capacity (although the latter would be useful for loading cargo, the *Empress Marava* already mounts loading ramps in both its rear cargo door and airlocks). While not intended to land on rough or uneven terrain, it is capable of doing so; although *Empress Maravas* have been known to be abandoned after they could not take off from what previously seemed to be a safe landing site.

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TRAVELLER

SHIP OPERATOR'S MANUAL

Travelling is about the journey, not the destination, and few things shape a voyage across Charted Space as much as a starship. However, a starship is more than a mere means of transportation; it is also a home and a companion. To captain a starship is to be the master of one's destiny – for riches, glory, or an untimely end…

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